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A Performance Measurement Framework for a Small and Medium Enterprise

by:

Imran Ali ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

in

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Date: July 10th, 2003

University of Alberta

Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a Thesis entitled "A Performance Measurement Framework for a Small and Medium Enterprise" by Imran Ali in partial fulfillment of the requirements for the degree of Master of Science in Engineering Management.

Abstract

In a world of global competition, a company has to deliver services more effectively (i.e. better services) and more efficiently (i.e. more economically) than its competitor. This is especially difficult for small and medium sized enterprises (SMEs) due to their relative lack of organizational and management skills, lack of strategic planning and shortage of working capital. They are more vulnerable than the bigger, more stable companies whenever business circumstances change. They must spend their resources in areas, which ensure their business sustainability in the future.

This thesis provides an alignment of system dynamics and performance measurement. It analyzes how one can use system dynamics in developing a performance measurement framework. Various performance measurement frameworks are reviewed and candidate performance indicators for SMEs are chosen. A real SME is modelled using system dynamics in such a way that the performance, including a spectrum of indicators integral to the model, of the company can be estimated using the indicators. The model is verified against real performance data provided by the case study company. A study of the elements of the model and their relationships, together with a sensitivity analysis, yields a new practical performance measurement framework. An example of the use of the model in strategic planning for a SME is provided.

DEDICATION

I wish to dedicate this work to my parents. Without their support it would have been impossible for me to achieve my current success.

Thank you for so many wonderful things

ACKNOWLEDGEMENTS

I thank my research Supervisors Dr. Ted Heidrick, Dr. Stanislav Karapetrovic for their expert guidance throughout this endeavour.

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CHAPTER 1

INTRODUCTION

1.1 Performance Measurement

In order to assist companies achieve their goals and objectives, performance measures are used to evaluate, control and improve processes. Performance measures are also utilized to compare the performance of organizations, plants, teams and individuals as well as to assess employees.

Neely *et al.* (1995) state that performance measurement is literally the process of quantifying actions. To perform better, an organization has to achieve its desired goals with greater efficiency and effectiveness than its competitors (Neely *et al*, 1998). He defines "effectiveness" as the extent to which customer requirements are met, and "efficiency" as a measure of the resources used in order to achieve a desired level of customer satisfaction. Performance measurement also highlights the possibility that internal as well as external reasons can prompt specific courses of action. For example, with respect to one of the quality-related dimensions of performance – product reliability—"effectiveness" would mean achieving a higher level of product reliability, which might lead to greater customer satisfaction. In terms of "efficiency", achieving great reliability might reduce the costs incurred by a business through decreased field failures and warranty claims. Performance measurement is usually done by large companies, but small and medium businesses could also benefit from it.

1.2 Small and Medium Enterprises (SMEs)

Small businesses play an important role in the economy of any country because of their flexibility and ability to innovate. In nearly every country, they play a significant role in providing employment opportunities and supporting large-scale manufacturing firms (Gunasekaran *et al*, 2000). SMEs are critical to almost every national and local economy because of their potential to grow larger (Duan & Kinman, 2000). Small businesses are increasingly recognized as "the life blood of modern economics" (Ghobadian & Gallear, 1996). According to Industry Canada (2003)

> *A goods producing firm is considered "small" if it has fewer than 100 employees, while for service producing firms the cut-off point is seen as 50 employees. Above that size, and up to 500 employees, a firm is considered medium-sized. The term "SME" (for small and medium enterprise) is used to refer to all these components of the economy together.*

SMEs generally have limited resources in terms of working capital, people, management skills and strategic planning. Therefore, it is important to have good planning and proper management of these scarce resources. Having a performance measurement framework will help management to decide how to best use the company's scarce resources. The following section discusses the role of performance measurement in SMEs, the obstacles in adopting current performance measurement frameworks, and the basis for developing a new set of measures for SMEs.

1.3 Performance Measurement Frameworks (PMF) in Small and Medium Enterprises

Existing performance frameworks may not be suitable for SMEs for the following reasons:

- such frameworks may have too many performance measures which SMEs are not able to assess quantitatively because of a lack of resources (money and work force);
- traditional performance measurement frameworks include mostly financial measures which may not reveal anything in real time about the performance of the company; and
- exisiting performance measurement frameworks are generally applied to relatively stable companies but not for small businesses in which sales, or the number of employees, etc., varies rapidly over time.

The objective of this research is to develop a performance measurement framework capable of accounting for the dynamics of SMEs with a few simple measures.

1.4 Objectives and Methodology of the Research and Thesis Organization

The following section describes the objectives of the proposed research:

- to develop a model for performance measurement in a small business environment and to implement the model in a typical small-business manufacturing company;
- to develop a dynamic relationship among the different performance measures in the model, in order to help in indicating the most critical factors for achieving the company's goals; and

- to provide small business a way to make strategies to improve overall performance.

In order to meet the objectives of research, the research work is organized as shown in the Figure 1.1, in which:

- Chapter Two provides a survey of the existing literature, in order to present the background of the problems addressed in this thesis and also to determine what aspects of existing performance measurement frameworks might be adapted for SMEs.
- Chapter Three presents the theory behind the model of performance measurement based on a system dynamics. This chapter discusses why we are using the systems approach and how it helped in meeting the required objectives of our research by proposing a performance measurement framework model based on system dynamics.
- Chapter Four develops a computer model of a specific SME by using system dynamics. The chosen SME is typical of a small manufacturer. The model is calibrated on the basis of the company's actual performance.
- Chapter Five investigates with the help of sensitivity analysis, the effect of various performance measures on a company's performance. A final performance measurement framework is developed by including only those performance measures critical to the company's performance.
- Chapter Six offers conclusions and discusses the need for further research.

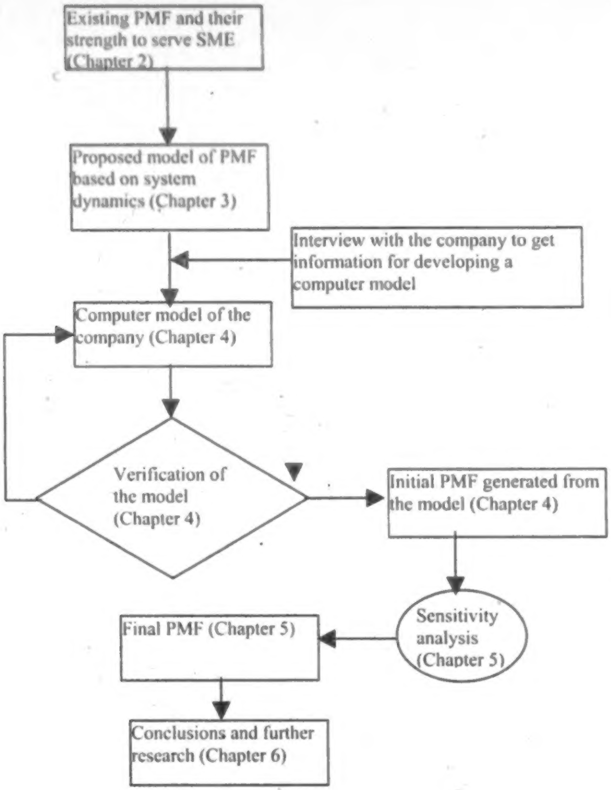

Existing PMF and their strength to serve SME (Chapter 2)
Proposed model of PMF based on system dynamics (Chapter 3)
Interview with the company to get information for developing a computer model
Computer model of the company (Chapter 4)
Verification of the model (Chapter 4)
Initial PMF generated from the model (Chapter 4)
Sensitivity analysis (Chapter 5)
Final PMF (Chapter 5)
Conclusions and further research (Chapter 6)

Figure 1.1: Methodology of the research and thesis organization

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

Previous research done on performance management and performance measurement is discussed in this chapter. The limitations of previous work in fulfilling the requirements of small and medium enterprises, and the reasons why they cannot use the existing performance measurement frameworks, are also investigated. In order to solve the problems of SMEs regarding performance measurement, the role of system dynamics is studied.

2.2 Performance Management

In a competitive and changing world, an organization has to deliver services better than its competitors, while remaining economic. An organization must use its resources efficiently while meeting its customers' needs. In other words, the processes of an organization have to be simultaneously efficient and effective. Merli (1996) referred to three principles that are required for success:

> *Success is a relative thing (Relativity Principle) and it is always determined by situations where there is an advantage over the competition. The competitive advantage is achieved and maintained only if the right improvement priorities are chosen (Priority Principle) and the ability to know how to obtain important results on these priorities (Effectiveness Principle).*

As the phrase indicates, "performance management" helps organizations to manage their overall performance in achieving their desired results. According to Neely *et al.* (1995) and Bititci *et al.* (1997), in order to achieve corporate strategies and goals, a company has to bring its performance in line with them. The process for developing this alignment is performance management, and the enabling activity for this process is performance measurement. According to Bititci *et al.* (1997), a performance measurement system plays the role of an information system in making performance management processes function effectively and efficiently.

Performance management requires an organization to determine goals and objectives while performance measurement is used to quantify the efficiency of the actions used in achieving the organizational goals and objectives (Neely *et al.*, 1995). In this way, the company's progress towards achieving the organizational goals can be tracked.

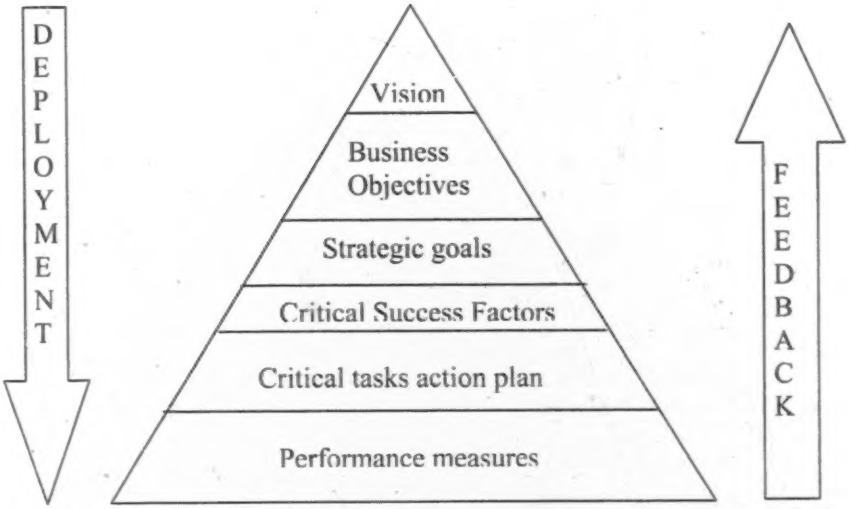

DEPLOYMENT
Vision
Business Objectives
Strategic goals
Critical Success Factors
Critical tasks action plan
Performance measures
FEEDBACK

Figure2.1: The closed loop deployment and feedback system for the performance management process (Source: Bititci *et al.*, 1997)

Bititci (1997) proposed a hierarchical structure for performance management in which performance measurement provides the feedback (Figure 2.1) that helps management in making decisions.

Once a goal or objective is achieved, new goals should be set to continue the cycle. Both performance measurement and improvement are essential if an organization wishes to simultaneously achieve its objectives and maintain its competitive edge.

2.2.1 Models for Performance Management

An organization can use several ways to measure its performance and plans for achieving continuous improvement. The most prominent frameworks for quality and performance excellence that have had worldwide influence are the ISO 9000, the Malcolm Baldrige National Quality Award criteria, the Deming Prize, and the European Quality Award. A new emerging philosophy called "Six Sigma" can also be used as a performance management framework. All these frameworks are based on total-quality management techniques as a means of achieving performance excellence and are discussed in detail in the following sections.

2.2.1.1 ISO 9000 Series

"ISO" is derived from the Greek word "isos" meaning "equal." It was introduced 50 years ago by the International Organization for Standardization (ISO), an internationally recognized federation of the national standards bodies from 130 countries (Leland, 2000). Introduced in 1987, the ISO 9000 is a set of five standards for quality assurance. Increased international competition with respect to manufactured products led to worldwide adoption of these quality standards. The ISO 9001, ISO 9002, and ISO 9003 are intended to be used as specifications for quality-management systems, whereas the ISO 9000 and ISO 9004 are documents providing guidelines for the application of the required specification of the quality management system. The three quality standards guide a company in the areas of design/development, production, installation, and service. According to Quazi and Padibijo (1998), the ISO 9000 series has been perceived and adopted as an initial stage in many manufacturing organizations' attempts to achieve total quality. These standards are based on the idea that a well-implemented quality-assurance system provides confidence that the company's output will meet the customer's expectations and requirements.

The ISO 9000 series is a prescriptive standard requiring documentation for all processes affecting quality. Auditing is performed to ensure compliance to a specific standard. The standards suggest that compliance through auditing leads to continuous improvement.

The major benefits of the standards are the following (Evans *et al.*, 2000):

- guidelines to achieve, maintain, and continuously improve product quality (including services);
- improved quality of operations to continually meet customers' and stakeholders' expectations and requirements; and
- through compliance, increased confidence for management and employees that the quality requirements are being fulfilled and that improvement is taking place.

Despite the worldwide recognition of the ISO 9000 (1994 version) series, it has many critics. Najmi and Kehoe (2001), Evans (2000), Najmi and Kehoe (2000), Karapetrovic, (1999), Dale (1999), Chin et al. (1995) have identified the ISO 9000's major problems, including the following:

- the standards do not specify any measure of quality performance; specific product quality levels are set by the company;
- too much emphasis is placed on documentation, creating a bureaucracy with respect to control mechanisms, and bottlenecks when documents need to be changed or updated;
- there is a lack of emphasis on continuous improvement;
- the standards do not consider activities such as leadership, strategic planning, or customer relationship management;
- the standards are frequently mistaken for a guarantee of product quality;
- the ISO series does not include a strong focus on customer satisfaction; and
- the ISO 900 series is generic and represent the minimum requirements for an effective quality system.

To overcome the core shortcomings of the ISO 9000 in providing a complete and dynamic system to achieve business excellence, structural changes were necessary. In December 2000, the ISO 9000 series was updated for the second time. The 1994 version, which emphasized quality assurance, has now been replaced by the ISO 9001:2000, which was developed to assist organizations to implement and operate quality-management systems.

The revised ISO 9001 and ISO 9004 standards were developed as a consistent pair of standards. The revised ISO 9001 addresses the requirements for the quality management system for an organization. The revised ISO 9004 provides guidelines to lead beyond the ISO 9001 to enhance the interested parties' satisfaction.

Both the ISO 9001 and ISO 9004 use the common vocabulary as defined in the ISO 9000. The editions of the ISO 9001, ISO 9002 and ISO 9003 standards were merged into the single ISO 9001:2000 standard, which is based on eight management principles: (1) customer-focused organization, (2) leadership, (3) involvement of people, (4) process approach, (5) systems approach to management, (6) continual improvement, (7) factual approach to decision-making, and (8) mutually beneficial relationships with suppliers.

The revision of the ISO 9000 quality system standards includes a fundamental change to the structure of ISO 9001 and ISO 9004 while maintaining the essence of the original requirements. The revised version reclassifies the 20 elements of the ISO 9000:1994 into five main categories:

- quality management,
- management responsibility,
- resource management,
- product realization, and
- measurement, analysis and improvement.

The structure of the ISO 9000:2000 version is based on the process approach, more focus on customer-orientation and the Deming Wheel or PDCA (Plan, Do, Check, and Act) cycle, which has been a part of quality management systems for years. Although the new version's PDCA cycle helps companies to improve continuously, the ISO 9000 series is a prescriptive standard requiring documentation for all the processes affecting quality, without specifying any measure of performance. For example, when requiring documentation for its element 7.3.2, i.e., "design and development inputs", the ISO 9000 states, *"Input relating to product requirements shall be determined and records maintained…."*

Because of all the documentation required for certification, as well as the high cost of registrations, the scarce resources of SMEs may prevent them from using the ISO 9000.

2.2.1.2 The Malcolm Baldrige National Quality Award

The Malcolm Baldrige National Quality Award (MBNQA) has been one of the most powerful catalysts behind the move towards achieving total quality in the United States and, indeed, throughout the world. This award is named for Malcolm Baldrige, who served as Secretary of Commerce from 1981 to 1987 because of his managerial excellence in improving the efficiency and effectiveness of government (NIST, 2002).

The Baldrige Award's Criteria is a non-prescriptive framework for performance excellence and is designed to encourage companies to enhance their competitiveness through efforts to achieve two results-oriented goals:

- the delivery of ever-improving value to customers, resulting in improved marketplace success, and
- the improvement of overall company performance and capabilities.

The criteria consist of seven categories: (1) leadership, (2) strategic planning, (3) customer and market focus, (4) information and analysis, (5) human resource focus, (6) process management, and (7) business results.

These seven categories form an integrated management system (see Figure 2.2 below).

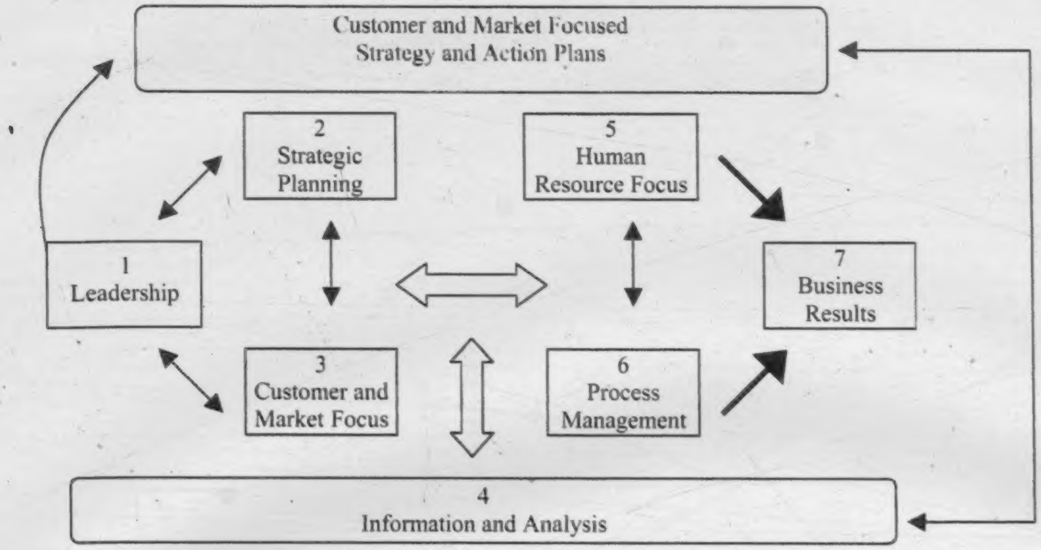

Customer and Market Focused Strategy and Action Plans
2 Strategic Planning
5 Human Resource Focus
1 Leadership
7 Business Results
3 Customer and Market Focus
6 Process Management
4 Information and Analysis

Figure 2.2: MBNQA Framework 2001 (Source: NIST, 2002)

This model has two triads. Leadership, Strategic Planning, and Customer and Market Focus form the first triad. Senior leaders must set organizational direction and seek future opportunities – these activities are the role of strategic planning. Senior leaders must also focus on customers, or the organization as a whole will lack that focus. Human Resource, Process Management, and Business Results form the "results triad." An organization's employees and its key processes accomplish the work of the organization in achieving its business results, toward which all actions point. Finally, Information and Analysis support the entire framework by providing the foundation for performance measurement and a fact-based approach for improving performance and competitiveness. Organizations are evaluated against a given set of criteria, and a maximum of 1000 points are allocated among the award's seven criteria. Each criterion has a different number of points in accordance with its relative value within the award. Thus, the MBNQA criteria define both an integrated infrastructure and a set of fundamental practices for a high-performance management system (Evans *et al.*, 2000).

However, the criteria do not prescribe specific quality tools, techniques, technologies, systems or starting points. Companies are encouraged to develop and demonstrate creative, adaptive, and flexible approaches to meeting basic requirements. Like all quality-management systems, the MBNQA is also based on using the PDCA cycle to improve the performance of a company continuously. The MBNQA is typically used by well-established businesses and requires an alignment of a company's processes with the seven criteria categories. In order to score high and compete for the award, a company has to provide evidence of satisfying each of the seven criteria. Moreover, like the ISO 9000 series, the MBNQA requires documentation for all of a company's processes, and for this reason may not be adopted by SMEs.

2.2.1.3 The European National Quality Award

The European Quality Award (EQA) was officially launched in 1991. Its primary purpose is to support, encourage and recognize the development of effective total-quality management by European companies. The EQA is managed by the European Foundation for Quality Management (EFQM), established in September 1988.

The EFQM Model is a non-prescriptive framework recognizing that many approaches can be used to achieve sustainable excellence. Within this non-prescriptive approach, some fundamental concepts which underpin the EFQM model, are:

- results orientation (achieving results that delight all the organization's stakeholders),
- customer focus (building strong relationships with the customers),
- leadership and consistency of purpose (leaders who set their goals clearly and communicate a clear direction to their organization),
- management by processes and facts (systematic implementation of policies, objectives, and strategies through a clear set of processes and decisions made on factually reliable information),
- people development and involvement (maximizing the contribution of employees through development and involvement),
- continuous learning, innovation and improvement (creating innovation and improvement opportunities through learning from within the organization and from others),
- partnership development (developing and maintaining value by establishing partnerships with customers, suppliers, and society), and
- public responsibility (meeting and exceeding the minimum expectation and regulations of the local and, where appropriate, the global community).

The EFQM Excellence Model is based on nine criteria (Figure 2.3). Five of these are "Enablers" and four are "Results." The "Enabler" criteria cover what an organization does. The "Results" criteria cover what an organization achieves. "Enablers" cause "Results" and feedback from "Results" helps to improve "Enablers."

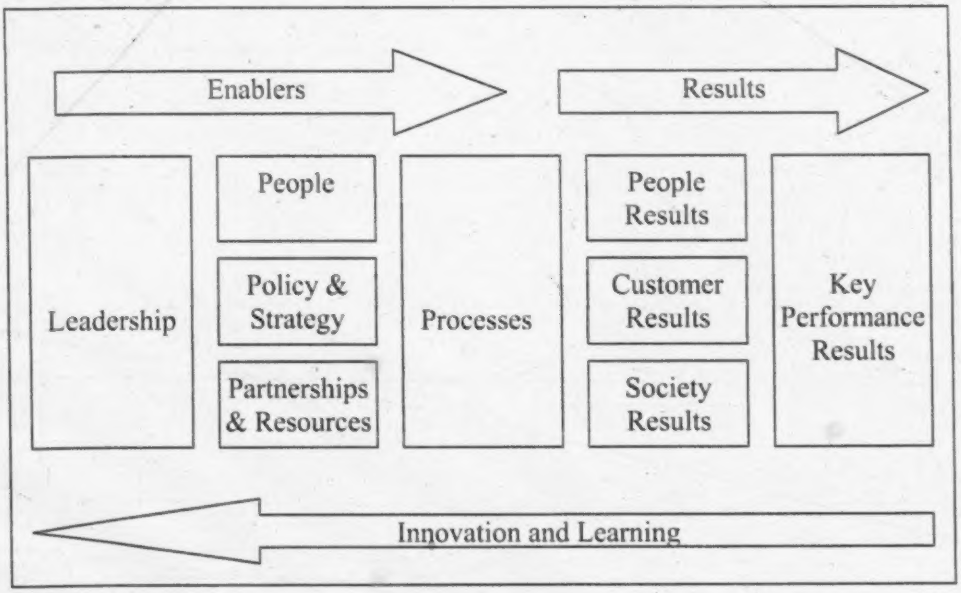

Enablers
Results
Leadership
People
Policy & Strategy
Partnerships & Resources
Processes
People Results
Customer Results
Society Results
Key Performance Results
Innovation and Learning

Figure2.3: Enablers and results of the EQA (EFQM, 2002)

The EQA model attempts to describe the main elements of the TQM concept. The model is prescriptive in terms of the philosophy and values which it explains, but it does not stipulate any particular tools, methods, procedures, or practices, as the MBNQA does. It is based on the apparently sound and logical assumption that the end results are the by-product of enablers (Ghobadian & Woo, 1994).

Each criterion has a different number of points in accordance with its relative value within the award. The award is very similar to the MBNQA, for both these awards address the same aspects and require a company to make a sustained effort in order to satisfy the requirements.

2.2.1.4 The Deming Prize (DP)

The Union of Japanese Scientists and Engineers (JUSE) instituted the Deming Prize in 1951 in recognition and appreciation of W. Edwards Deming's achievements in statistical quality control. According to Ghobadian and Woo (1994), the primary purpose of this framework is to improve the performance of the company by implementing company-wide or total quality control (CWQC or TQC) based on statistical quality control techniques.

The DP was established to ensure that good results are achieved through successful implementation of CWQC activities. Its framework focuses on the implementation of a set of principles and techniques, such as process analysis, statistical methods and quality circles. Therefore, most of its criteria are confined to the application of these principles and techniques (Bohoris, 1995). The judging criteria consist of a checklist of ten major categories:

1. policies,
2. the organization and its operation,
3. education and dissemination,
4. information gathering, communication and its utilization,
5. analysis,
6. standardization,
7. control /Management (control of processes and decisions based on reliable information),
8. quality assurance,
9. effects, and

10. future plans.

Each major category is divided into subcategories and weighted equally. Because it names specific techniques and approaches, the checklist is inherently prescriptive (Ghobadian & Woo, 1994), and a company has to satisfy each criterion in order to achieve the award.

Table 2.1 summarizes the advantages and disadvantages of all the above discussed performance management frameworks and their strengths in relation to SMEs.

Framework	**Advantages**	**Disadvantages**	**Ability to serve SMEs**
ISO 9000	1. It is a prescribed framework; a company knows exactly what to do in order to achieve the award. 2. Internationally recognized and assures a product's conformance with the said specifications.	1. It requires documentation for all the processes covered by the award. 2. It prescribes minimal requirements for quality. 3. Focuses only on the results relating to a company's products.	Not helpful for the start-up of a SME, as money and time are required to implement the ISO 9000 and get registered.
MBNQA	1. It is a total quality management framework that covers all aspects of an organization. 2. Internationally recognized. 3. Fosters continuous improvement.	1. Non-prescriptive framework; does not say what to do or how to meet its requirements. 2. Not helpful for start-up of small companies. 3. Requires significant time and resources to achieve.	Not helpful for SMEs, as money and time are required to implement it.
EQA	Same as the MBNQA, except that this award is more popular in European countries.	Same as the MBNQA	Not helpful for SMEs, as money and time are required to implement it.
DP	1. It is a prescribed framework; a company knows exactly what to do in order to meet the award criteria. 2. Fosters statistical quality control techniques to achieve results. 3. Less internationally recognized than the other frameworks.	1. This framework requires implementation of statistical quality-control techniques throughout a company; requires training of employees to understand and to use those techniques. 2. It requires documentation of all the related processes.	Not helpful for SMEs, as money and time are required to implement it.

Table 2.1: Summary of all the performance management frameworks

After above discussion it is obvious that none of the existing performance management framework will work for the SMEs. SMEs need a simple performance management framework that can help them in improving their performance and require less money and time. The next section discusses the *performance measurement* needed for any of the *performance management* frameworks discussed in the previous section; for example auditing is required for performance measurement when using the ISO 9000.

2.3 Performance Measurement

"Performance measurement" is a process of measuring performance. The discussion above explains the frameworks that can be used to manage performance, but in order to manage anything, it must be measured. For a prescriptive performance management framework like the ISO 9000 series, auditing is a part of the performance measurement framework; auditing assures compliance to the minimal standard of quality but does not lead to continuous improvement. In order to exceed the minimal requirements, an organization must improve continuously. For non-prescriptive performance management frameworks like the MBNQA, performance measurement is done by self- assessment. The performance measurement helps organizations in establishing which critical aspects must be managed to achieve the desired organizational goals. This section will discuss the role of performance measurement and also the performance measures proposed by different authors.

2.3.1 Role of Performance Measurement

According to Neely (1998), the primary role of measurement is to help managers understand how their organization is performing now and how this performance can be improved. Hatry (1999) referred to performance indicators as the dials in a dashboard, and to business managers as automobile drivers and airplane pilots who need to monitor these dials in order to reach the desired destination. During this journey, managers/drivers have to make different decisions based on the information obtained from these dials (performance indicators). Figure 2.4 below illustrates the role of performance measurement in managing performance. The performance measurement framework helps management to develop strategies in order to achieve the desired goals. The basis of the framework is similar to that of the Bititci and Muir (1997) hierarchical structure for performance management (Figure 2.1).

Performance measurement systems enable managers to make informed decisions and to take appropriate actions because these systems quantify the efficiency and effectiveness of past actions. This process includes collecting, categorizing, analyzing, and distributing the appropriate data (Neely *et al.*, 1998).

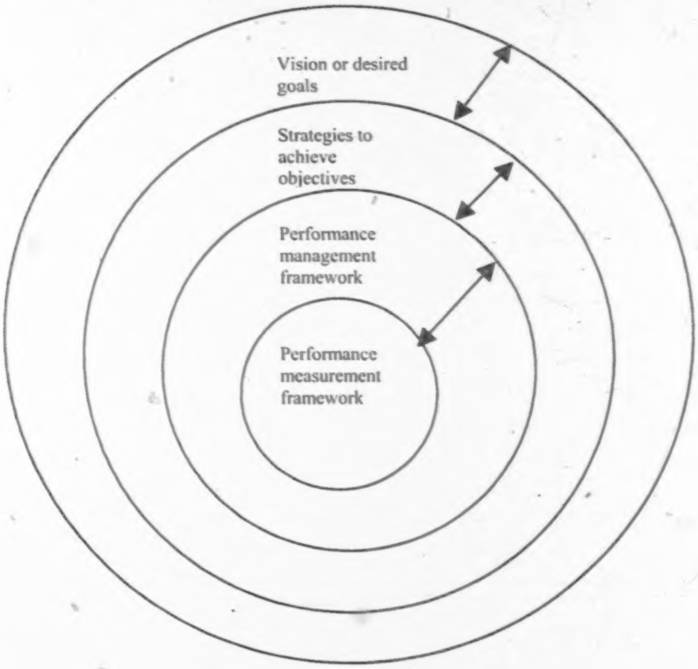

Vision or desired goals
Strategies to achieve objectives
Performance management framework
Performance measurement framework

Figure2.4: Role of performance measurement in managing the performance

According to Browne *et al.* (1997), performance improvement cannot be achieved without performance measurement. To improve, a company must have a process of measurement that measures both the present performance and the performance after any changes have been made.

Neely *et al.* (1995) discussed the role of performance measurement as a process of quantifying the efficiency and effectiveness of a company's actions. This definition implies that improvement focuses not only on getting the desired results but also on including how these results have been achieved. To perform better, an organization has to achieve its desired goals with greater efficiency and effectiveness than its competitors (Neely *et al.*, 1998).

The elements of performance measurement include a performance measure, which describes the nature of measure; performance indicators describing the units of the measure; and the performance measurement data showing the results of the performance measure and performance indicators (Browne *et al.*, 1997). In the example discussed above of the dashboard in an automobile, speed would be a measure; a calibrated dial would be an indicator, and the data recorded over time would give feedback to a driver about the speed. All these performance measures make up the performance measurement framework.

The role of performance measurement can be summarized as follows (Neely *et al.*, 1998; Oakland, 1989):

- ensuring customer requirements,
- providing standards for establishing comparison,
- providing feedback for people to monitor their own performance levels,
- highlighting quality problems and determining which areas most need attention,
- giving an indication of the costs of poor quality,
- justifying the use of resources, and
- providing feedback for driving the improvement effort.

2.3.2 Development of Performance measurement Systems

2.3.2.1 Traditional Performance Measurements Systems

According to Browne *et al.* (1997), traditional performance measurement systems were developed in the late nineteenth and early twentieth centuries and included only financial measures such as Return on Investment (ROI), Return on Equity (ROE), and Return on Sales (ROS).

In the SME's rapidly changing business environment, these measures have become less relevant than they were previously. Many authors (Chakravarthy, 1986; Carlin, 1999; Kaplan & Norton, 1992; Maskell, 1991) have discussed the problems resulting from the use of these traditional performance measurements, such as:

- traditional measures are inadequate for evaluating a firm's strategic performance;
- they concentrate on the end results rather than the means by which these end results are attained;
- these measures are not directly related to the manufacturing strategy and are not meaningful for controlling the production and distribution processes;
- traditional performance measurement systems are not flexible;
- these measures have produced irrelevant or misleading information that has undermined the achievement of strategic objectives;
- traditional performance measures do not take into account the requirements and perspective of customers; and
- bottom-line financial measures come too late for taking any corrective actions.

According to Neely (1999) and Keegan *et al.* (1994), the problem with traditional performance measures used in many organizations is that they are rarely integrated with each other or aligned with the business process.

2.3.2.2 Guidelines for Modern Performance measurement Systems

Because of its inability to provide required information in real time and to encourage improvement, traditional performance measurement needs radical changes, which, in turn, require a shift from treating financial figures as the foundation for performance measurement to treating them as one measure among many (Eccles, 1991). According to Eccles (1991), companies now realize that their existing performance measurement system, which is largely financial, is not truly improving their overall performance. For overall improvement, companies have to develop performance measures based on those factors that influence the satisfaction of the customers' requirements.

Various authors (Browne *et al.*, 1997, Maskell, 1991, Neely *et al.*, 1997) explained that performance measures should

- be related to the company's main strategies; i.e. be related to specific targets;
- provide fast feedback;
- be a part of closed management loop;
- be clearly defined and easy to understand;
- include non-financial measures;
- vary between locations;
- change over time as needs change; and
- be used to foster improvement not to reduce variance.

For managers of companies, taking a whole systems approach or understanding how all areas of the organization are performing is becoming increasingly important. If properly constructed, performance measures provide information to management to enable fact-based decision-making about processes. As well, performance measures are also important for effective communication. Their use can increase constructive problem-solving, monitors progress, and gives feedback and reinforces behavior (Sinclair and Zairi, 1995).

2.3.3 Performance Measurement Frameworks

In the last two decades, much work has been done on new approaches to performance measurement. The balanced scorecard approach developed by Kaplan and Norton (1992) is probably the most well-known performance measurement framework (Figure 2.5). Its purpose is to report on strategic performance. The framework divides the measures into four categories of perspective:

- Financial perspective: how do we look to our shareholders? (Includes measures like operating income, return-on-capital, and sales growth ratio);
- Internal Business perspective: what must we excel at? (These measures focus on the internal processes that will have the greatest impact on customer satisfaction and achievement of an organization's financial objectives);
- Customer perspective: how do our customers see us? (Includes measures like customer satisfaction, customer retention, new customer acquisition, and market share.); and
- Innovation and Learning perspective: how can we continue to improve and create value? (Includes measures like employee satisfaction, retention, training, and skills).

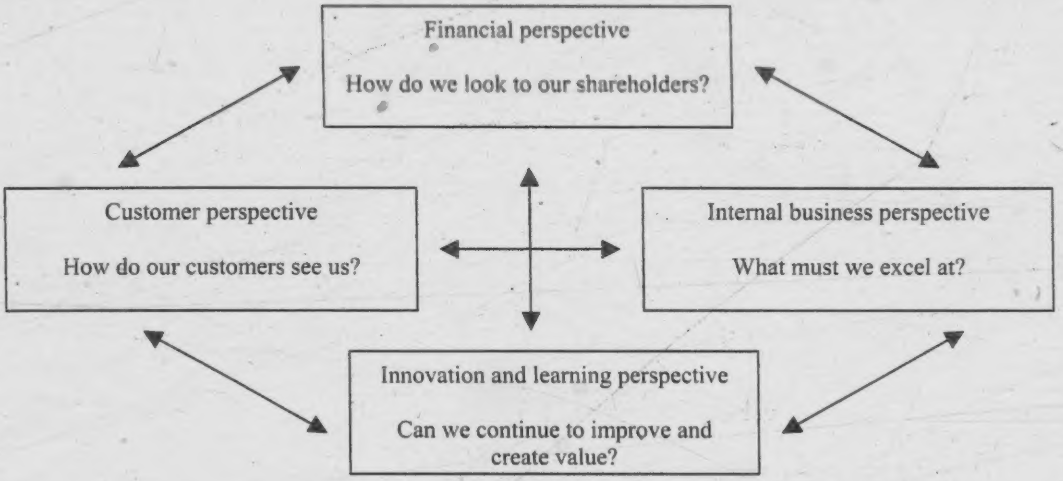

Financial perspective
How do we look to our shareholders?
Customer perspective
How do our customers see us?
Internal business perspective
What must we excel at?
Innovation and learning perspective
Can we continue to improve and create value?

Figure 2.5: Balanced scorecard (Source: Adapted from Neely *et al.*, 1995)

As discussed earlier, “performance” or “success” is a relative thing, and according to Neely *et al.* (1995), the balanced scorecard approach contains a serious flaw because it is not able to answer the question, “What are our competitors doing?”

Keegan *et al.* (Figure 2.6) proposed a performance measurement similar to that of the balanced scorecard but less well-known. The strength of this matrix lies in its capacity to integrate different dimensions of performance and its ability to include cost and non-cost measures enhancing its flexibility. Keegan *et al.* (1989) also supported the idea that performance measures should be driven by strategy and should provide linkage between the different units of the business and its strategic plans. Keegan *et al.* (1994) emphasized that a company should reduce the number of data-collecting points. According to these writers, the use of the milestone reporting of production and of predetermined estimates of cost will make the system less expensive and more relevant than it would be otherwise.

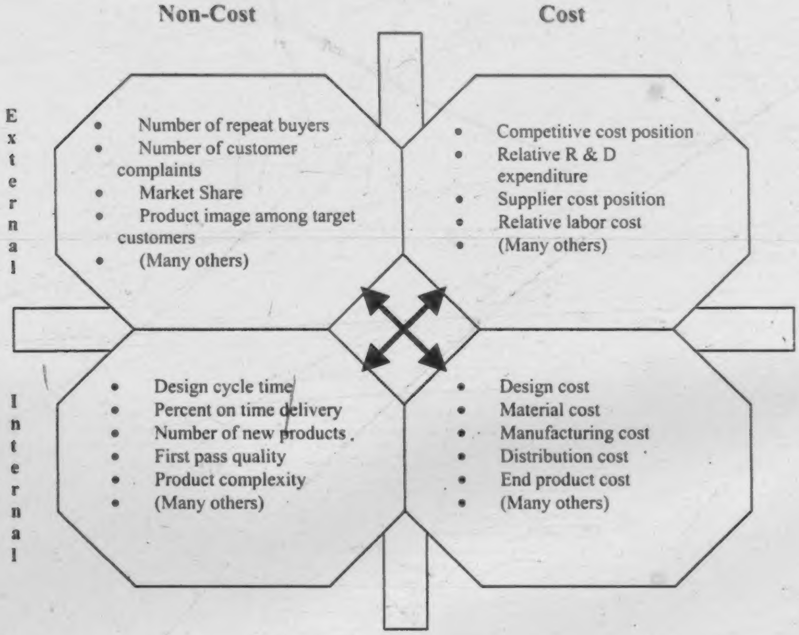

Non-Cost
Cost
External
Internal
Number of repeat buyers
Number of customer complaints
Market Share
Product image among target customers
(Many others)
Competitive cost position
Relative R & D expenditure
Supplier cost position
Relative labor cost
(Many others)
Design cycle time
Percent on time delivery
Number of new products
First pass quality
Product complexity
(Many others)
Design cost
Material cost
Manufacturing cost
Distribution cost
End product cost
(Many others)

Figure 2.6:Keegan's supportive performance measures (From Keegan *et al.*, 1989)

According to Keegan *et al.* (1989),

> *The problem with companies is not that they lack performance measures, but they have too many—and too many irrelevant ones... start broad not bottom up. If in doubt establish five overall performance measures and let others derive from this set: quality, customer satisfaction, speed, product (or service) cost reduction and cash flow from operations.*

As small businesses may lack performance measurement frameworks, these businesses should start with simple performance measures in their performance measurement framework, as suggested by Keegan *et al.* (1989 &1994). Small businesses should strive for simplicity and keep their performance measurement system focused and simple.

The ENAPS (European Network for Advanced Performance Studies) approach is process-oriented and its measures and indicators are quantitative and related to high-level macro-measures of performance such as time, cost, and quality. The ENAPS (Browne *et al.*, 1997) performance measurement system attempts to combine the best ideas from previous performance measurement systems. It has a generic set of performance measures and indicators and uses a process-oriented, top-down approach to develop performance measures and indicators based on a sound business model.

The performance measures used in calculating performance indicators are measured from all over the enterprise under the following eight headings: Accounts, Product Development, Marketing and Sales, Planning and Production, Customer Service, Purchasing, Personnel and others. All these measures should be suitable for nearly all manufacturing enterprises at all levels; i.e., the enterprise level, process level, and function level.

Therefore, the ENAPS system provides a complete set of measures and indicators, so that the members of the enterprise can understand how their decisions and activities affect the entire business and also so that the members compare these performance indicators with the best practices within their industry. Generally, however, this approach cannot be used by small and medium-sized businesses because of a lack of resources (money and work force) and the cost in documentation and labour to establish this approach.

According to Neely *et al.* (2001a), a “performance prism” is the second generation of performance measurement framework, coming after the balanced scorecard. Neely *et al.* (2001) argued that the balanced scorecard was the best framework when it first appeared because it addressed the need for a balance between financial and non-financial measures, but with the passage of time, the priorities of businesses have changed. For example, a performance- management framework now needs to be able to measure the supplier's performance but the balanced scorecard does not do so. To address these changes, companies need the second generation of the performance measurement framework, which helps long-established companies to update their balanced scorecard and newly established companies to develop performance indicators according to their business needs. The performance prism consists of five interrelated facets: Stakeholders, Strategies, Processes, Capabilities, and Stakeholders Contribution. According to Neely *et al.* (2002), one of the major fallacies of performance measurement is that measures are derived from strategy. However, organizations have strategies only to deliver value to their stakeholders, so an organization must identify its potential stakeholders before deciding upon any strategy.

2.3.4 Development and Implementation of Performance Measures

Neely *et al.* (2000) proposed that the development of performance measurement systems can be divided into three main phases (see Figure 2.7):

1. the design of the performance measures,
2. the implementation of the performance measures, and
3. the use of the performance measures.

The framework proposed by Neely has two functions. First, it describes the design and implementation of performance measures; second, it suggests four processes for updating the performance measures. The updating process of the performance measurement framework requires:

- an effective mechanism for reviewing the targets,
- performance measures that change as circumstances change,
- a performance measurement system that includes a process of periodically reviewing the performance measures, and
- a performance measurement system that challenges the company's strategy.

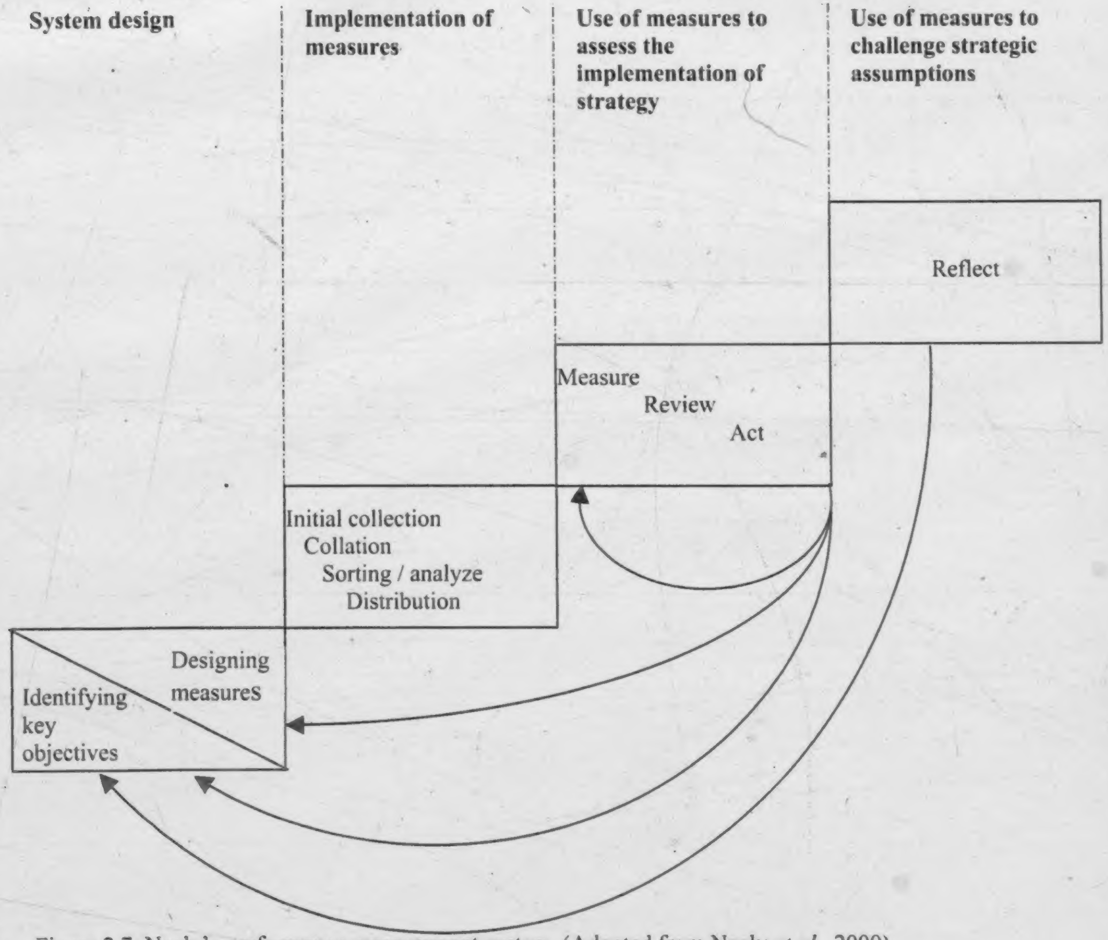

System design
Implementation of measures
Use of measures to assess the implementation of strategy
Use of measures to challenge strategic assumptions
Reflect
Measure
Review
Act
Initial collection
Collation
Sorting / analyze
Distribution
Designing measures
Identifying key objectives

Figure 2.7: Neely's performance measurement system (Adapted from Neely *et al.*, 2000)

2.3.5 Performance Measures

According to Neely (1997), the following measures are important in a manufacturing company:

Category of measure	**Measure used**
Shipments	Actual (delivered orders) Current backlog
Inventories	Total (Weeks and $) Scrap (amount of scraped products) Excess (amount of excessive products) Obsolete (amount of products that has been obsoleted)
Variance	Purchase price (purchase price of the raw material) Material Usage Labor
Labour Performance	Efficiency Utilization Productivity Overhead percentage Overtime Absenteeism Indirect: direct ratio
Capital	Appropriations Expenditures
Spending	Salaries and benefits Controllable expenses Non-Controllable expenses
Headcount	Direct Indirect Total By functional areas

Table 2.2: Performance measures for a manufacturing company (Adapted from Neely *et al*., 1997)

Neely (1997) explained that the key dimensions of a manufacturing company's performance can be defined in terms of quality, delivery speed, delivery reliability, price, cost and flexibility. All these performance measures may be useful for SMEs, but we need to understand more about them before we make a final selection because the existing frameworks for performance management and performance measurement may be useful for large companies but not for SMEs.

Since the main topic of this study is performance measurement in small and medium enterprises, the following section describes the definition and importance of small businesses, the problems they face, and the solution to their problems.

2.4 Small and Medium Enterprises

The size of the businesses and the increasingly competitive markets force small and medium enterprises to consider more cost-effective processes than large enterprises must consider. As well, small businesses have to deal with unique operational and limited financial and economic resources.

2.4.1 Definition of Small and Medium Enterprises

The expression "small firm" has no single definition, mainly because of the wide diversity of businesses. In the literature, some of the most widely used criteria to delineate a "small business" include size, number of employees, sales volume, asset size and type of customers.

In some sectors, "size" can be most appropriately defined by the number of employees, but in other sectors, turnover can be the most appropriate criterion. According to Industry Canada (2003), size is usually measured according to the number of full-time employees or their equivalent in a company. A company is "small" if the number of employees is:

- not more than 50 employees for a service company, or
- not more than 100 employees for a goods producing company.

Above these sizes, and up to 500 employees, a firm is considered "medium-sized."

2.4.2 Importance of SMEs

Small and medium enterprises (SMEs) play an important role in modern economies because of their flexibility and ability to innovate. In nearly every country, SMEs play a significant role in providing employment opportunities and supporting large-scale manufacturing firms (Gunasekaran *et al.*, 2000). SMEs are being increasingly recognised as "the life blood of modern economics" (Ghobadian & Gallear, 1996).

Small and medium enterprises are key contributors to the Canadian economy. They are the suppliers of products to large companies and incubators for new products, processes, and services. According to Statistics Canada, SMEs have been the largest job creators in Canada during the last few years. Of all these SMEs, only 15% account for creating 85-90% of the job growth, mainly in the high-technology sector (APRO, 1992).

2.4.3 Problems Facing SMEs

Small businesses are critical to almost every national and local economy because of their potential to grow larger (Duan and Russell, 2000). Their problems are not similar to those of larger organizations and have not been treated with the same importance as those of larger businesses.

The major problems facing SMEs are (Woodcock *et.al.*, 2000):

- lack of organizational and management skills;
- lack of strategic planning and documentation;
- susceptibility of their products to obsolescence and technological change;
- inconsistent record-keeping for evaluation;
- shortages of working capital and credit; and
- inadequate knowledge of the competitors' products.

The next section discusses the need of small and medium enterprises trying to overcome the aforementioned problems.

2.4.4 Needs of SMEs

Although large and small businesses deal with many of the same issues, smaller businesses also deal with unique size-related issues as well and behave differently in their analysis of, and interaction with, their environment. Based on the problems faced by small businesses attempting to sustain their market share and to increase growth, they need some or all of the following:

- strategic and operational planning;
- management of human resources;

- decision making related to financial, technical and marketing issues; and
- performance measurement.

At this point, it is appropriate to describe these needs and how performance measurement relates to each.

A "strategic plan" is one that includes strategies indicating how objectives will be achieved. Strategic plans cover a one-to-five year time period. An "operational plan" is defined as a plan setting short-term objectives for specific functional areas such as finance, marketing and personnel. Operational plans cover planning periods of less than a year and are expressed in day-to-day terms. According to Shrader, Mulford and Blackburn, as cited in Temponi (1992), although operational planning is very important and commonly performed in small firms, they need to combine it with more strategic planning.

Small and medium businesses can benefit from both strategic and operational planning, depending on the state of the economy at a particular time. The state of the economy must be considered making strategic plans. According to Thune and House, as cited in Temponi (1992), a positive relationship exists between strategic planning and performance, and according to their research, the planners out-performed the non-planners. Garsombke and Garsombke, as cited in Temponi (1992), found that small firms using computerized systems for forecasting and aggregate planning, for example, financially outperformed those firms not employing such techniques. These results could have been due to some other factors. Therefore, small and medium businesses must do strategic planning for the future and select performance measures to help them in achieving the desired results. As stated by Davig as cited in Temponi (1992), "wait and see, and then react will mean being left behind".

In order to select performance measures critical to a company's overall performance, a good understanding of the whole business is needed. System dynamics can be used to model a company as a single "system". For the system to accomplish its desired goals, its different parts must work harmoniously with each other and the model can be used to assess these interactions.

2.5 System Dynamics

2.5.1 Introduction

We live in a world where everything affects everything else. Dr. J.W Forrester started industrial dynamics late in the 1950's in order to understand the new socio-technological factors that companies then had to deal with. According to him, " The human mind, through the mental models it establishes, cannot cope with the many time-varying and often delayed aspects of today's complex society". We use mental models in our daily activities, and in reaching any decision it certainly makes the trade offs, but often with the wrong factors (Forrester, 1961). System dynamics is a way of integrating separate functional areas of management. Understanding a system's dynamics helps in identifying the critical factors affecting the system's ability to achieve desired goals.

A systems approach helps us to understand the structure and dynamics of complex systems (Sterman, 2000). "Structure" means the components of a system, and "dynamics" refers to the interactions of these components in order to achieve a system's targets.

Over the past decade, a systems approach has been applied to various fields including auditing, management systems (Karapetrovic & Willborn, 1998A), and organizational policy-making, in order to address the critical issues of an organization's system. Understanding this approach involves a two-stage methodology. The first step is to map out the system or a model of the system, including all the components that need to act harmoniously in order to achieve the desired goals. This step is very critical because too much or too little information may cause a misunderstanding of the entire system. According to Sterman (2000) and Forrester (1961), this approach can help in modeling any process and identifying factors causing problems in a system. Once a model has been prepared, it can be validated. Historical data are required to determine if it is generating the existing state of the system. This step is iterative in nature and may require some information that was not obtained earlier.

The following section discusses the categorization of any system and the basis on which the system works.

2.5.2 Social Theories and the Systems Approach

Burrell and Morgan (cited in Jackson, 2000) explained that social theories can either implicitly or explicitly provide "frameworks of ideas" to which existing systems approaches are related. According to these authors, a system can be of two types:

An Objective system has an objective existence external to the individual. It attempts to establish the existing practices and casual relationships in the world. To get information about an objective system, scientific experiments and quantitative analysis can be used. Any mechanical or electrical system can be thought of an "objective" system.

A Subjective system deals with people rather than technology, structure or organization. Its primary area of concern is perceptions, values, beliefs and interests.

Each type of system can be further divided in two categories: regulation and radical change. The result is four frameworks of ideas for the systems approach (Figure 2.8).

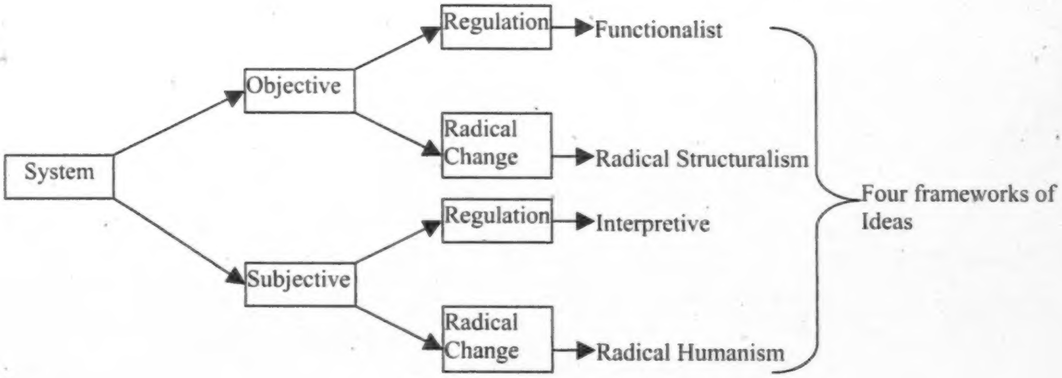

Regulation
Functionalist
Objective
Radical Change
Radical Structuralism
System
Four frameworks of Ideas
Regulation
Interpretive
Subjective
Radical Change
Radical Humanism

Figure 2.8: Frameworks of ideas for the systems approach

Interpretive Approach System: This system is subjective and regulatory in nature. To understand such a system, understanding the point of view and the intentions of the persons who constructed the system is required. Studying such a system facilitate prediction of what the status quo will be and of controlling it in the future.

Radical Structuralism Approach System: This system needs radical changes to achieve its objectives. Understanding such a system facilitates the emancipation of people from the existing structures. Emphasis is placed upon the contradictions in the system and the conflicts among its groups.

Radical Humanism Approach System: This system is subjective and based on radical changes. Emphasis is placed upon understanding the current social arrangements that are constraining human development.

Functionalist Approach System: This system has an easily identifiable existence independent of observers. We can understand the workings of such a system if we can find regularities in the relationships between the sub-systems and the whole. The human beings in the system present no more problems than do the other component parts. A model of the system can be constructed. The purpose of studying such a system is to understand the status quo better in order to facilitate predicting what the system will do and to control it in the future.

Alvesson and Deetz (cited in Jackson, 2000) described the following features of the functionalist approach (Table 3.1):

Features	**Functionalist Approach**
Basic goal	It demonstrates relationships between the different parts of the system
Method	System dynamics
Goals	Efficiency, effectiveness, survival and adaptation
Problems addressed	Inefficiency, disorder

Table 2.3: Features of functionalist approach (adapted from Jackson, 2000, pp. 198)

The objective of this research is to develop a performance measurement framework that will help small business to determine the performance measures that are the main contributors to their success or are very sensitive to their performance. To make this determination, a good understanding of how the performance measures interact with the company as a whole is required. The objectives of the functionalist approach are to demonstrate the relationships between the different parts of a system and to improve its efficiency. Therefore, we can use the functionalist approach to achieve the objectives of this research.

2.5.3 Role of System Dynamics in the Performance Measurement Framework

Any well-designed organizational process should include control mechanisms through which management can decide which aspects of the performance of a process are to be measured and how these measurements are to be used to change the level of resources utilized in the process (Stephen *et al.*, 2001). Management must choose which of several aspects of process performance to measure (e.g., cycle time, backlog, demand) and which parameters should govern the control process. Many different approaches have been proposed for creating and managing business processes (Bach *et al.*, 1996), but researchers take for granted that any well-engineered business process establishes measurements of process performance and influences process performance in a desired direction by using these measurements to control the process.

While the science of feedback control is highly evolved in the engineering disciplines within business process re-engineering (BPR) it has not evolved beyond the elementary level. Consider, for example, the following prescription for managing a business process (Stephen *et al.*, 2001):

"Process management plans, structures, and observes the process. . . . It determines the performance indicators for evaluating the process, sets objectives, compares targets with achievements, derives actions for improving the process and monitors process implementation."

Feedback control involves controlling the behavior of a system by measuring its state, comparing its current state to a desired state, and selecting control actions based on the differences between the actual and desired states (Forrester, 1961; Sterman, 2000).

According to Bititci *et al.* (1997), the objective of performance measurement is to provide a proactive closed-loop control system, in which the corporate and functional strategies are deployed to all business processes, activities, tasks and personnel, and feedback is obtained through the performance measurement system to enable appropriate management decisions.

To obtain feedback, a performance measurement framework can use system dynamics, as it can help in indicating the processes to control not only in the present but also in the future, and, thus, also help in achieving the organizational goals. Such a model can be developed in any system dynamics software (iThink, Stella, and Vensim, etc.) showing a dynamic relationship among all the chosen performance measures or in the components of the system (organizational model) to be observed. Figure 2.9 shows a performance management framework including system dynamics as a source of feedback and indicating the critical success factors for management in order to achieve organizational goals.

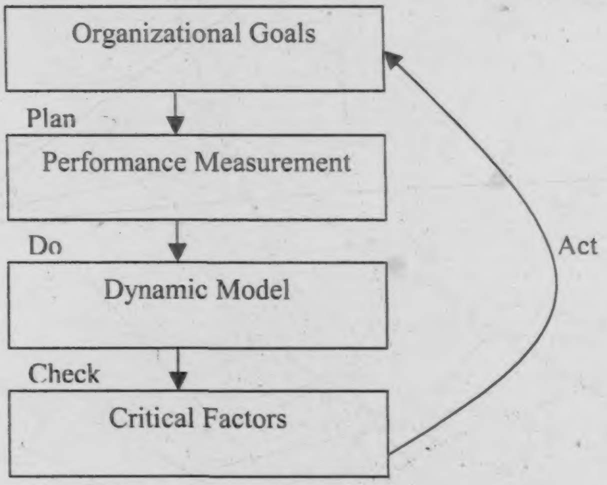


Figure 2.9: Performance management system based on a system dynamics approach

2.6 Motivation for the Proposed Research

Many organizations have competencies which do not yield any real competitive advantage. Conversely, some companies do not target those factors that could make a significant difference to their success (Thompson, 1998). Thompson and Richardson (1996) argue that an effective organization should measure those competencies that are most important for that organization's competitive and strategic success. These competencies will then receive attention and priority treatment, and improvements can be measured.

According to Manoochehri (1999), many companies have had very frustrating experiences in developing and using effective performance measures. The ENAPS (European Network for Advanced Performance Studies) approach provides a complete set of performance measures and indicators, but small businesses cannot use this approach, because they lack resources, and it is not cost-effective.

According to Neely (1999), measures have to be derived from strategy so he sought to document processes designed to help management teams to decide which measures are appropriate for their organization. Managers should prioritize those measures that have most impact on a company's goals and growth. Bititci (2000) proposed an integrated performance measurement system. According to him, a performance measurement system should be a dynamic system, which should have:

- an external monitoring system, which continuously monitors changes in the external environment;
- an internal monitoring system, which continuously monitors changes in the internal environment and raises warning and action signals when certain performance limits and thresholds are reached;
- a review system, which uses the information provided by the internal and external monitors and the objectives set by higher level systems, to decide internal priorities; and
- an internal deployment system to deploy the revised objectives and priorities to critical parts of the system.

The integrated performance measurement system is based on Deming's Plan, Do, Check and Act (PDCA) cycle. According to Bititci (2000), the combination of the existing performance frameworks and models together with an Information Technology (IT) platform could provide all the functionality required to create a dynamic performance system. Thus, computer models of the system (Dynamic model in Figure 2.9) should be made that continuously check the internal performance of the system to determine how it is responding to external changes.

Until now, no framework has had the ability to assist setting organizational priorities depending on the organization's goals. Existing performance measurement frameworks do not indicate the critical success factors having the most impact on a company's growth or other goals. The existing frameworks do prescribe the list of performance measures which a manufacturing company should measure, but without showing the dynamic relationship among these measures and without indicating the area most needing the company's resources.

CHAPTER 3

THEORETICAL MODEL FOR THE PERFORMANCE MEASUREMENT FRAMEWORK (PMF)

3.1 Introduction

This chapter presents the theory for the proposed model of a performance measurement framework based on a systems approach. This chapter discusses why the particular system dynamics approach (as discussed in Chapter 2) is used, and, how this helps in achieving the required objectives. The chapter provides a methodology for developing a performance measurement for small and medium enterprises.

3.2 Practical Applications of System Dynamics (SD) Theory

An organization should be seen as a whole system made up of interrelated parts (Jackson, 2000), which should be understood in terms of how they contribute to the maintenance of the whole organization. In order to improve the overall business performance, performance management (as discussed in Chapter 1) helps organizations to manage and improve their performance. The primary goal of an organization is to ensure its survival and continuity as a system. To do so, managers have to understand the various parts of their organization and their relationships among themselves and with the external environment.

According to Katz and Kahn (cited in Jackson, 2000):

> *" Organizations are best represented as entities in close relationships with their environments, taking inputs and transforming them in to outputs. These outputs in the form of products can provide the means to new inputs, so the cycle can begin again. The main purpose is to maintain a steady state and to survive."*

The above comments suggest that the outcome products influence the steady state and have an effect on the growth or survival of an organization as they are the generators of new inputs. For example, if the quality of a company's products were poor, the company would receive fewer new orders. If the delivery delay were too long or longer than that of the company's competitors, the company would also receive fewer new orders. Now consider a positive scenario. What if the quality and delivery delay of product were very good? The company would get more orders but does the company have capacity to fulfill these orders? The lesson here is that organizations have to adapt to changes in the external environment to achieve the desired goals.

Like information obtained from the traditional method of performance management, information from the performance measures gives feedback so that any needed corrective actions can be performed.

As the objective of the functionalist approach (discussed in Chapter 2) is similar to ours, we are using this approach to accomplish our required research objectives. The intention of the functionalist approach is to improve our understanding of the status quo to predict how the system will act and to control its action. Modeling the organization as a whole system with interrelated performance measures as different parts of the organization can achieve this goal.

Elements of this research include using the functionalist approach as a theory and system dynamics as a methodology and applying them to a real world-problem in improving business performance. Figure 3.1 shows the elements of this research.

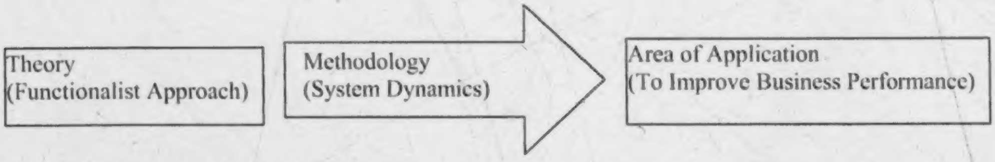
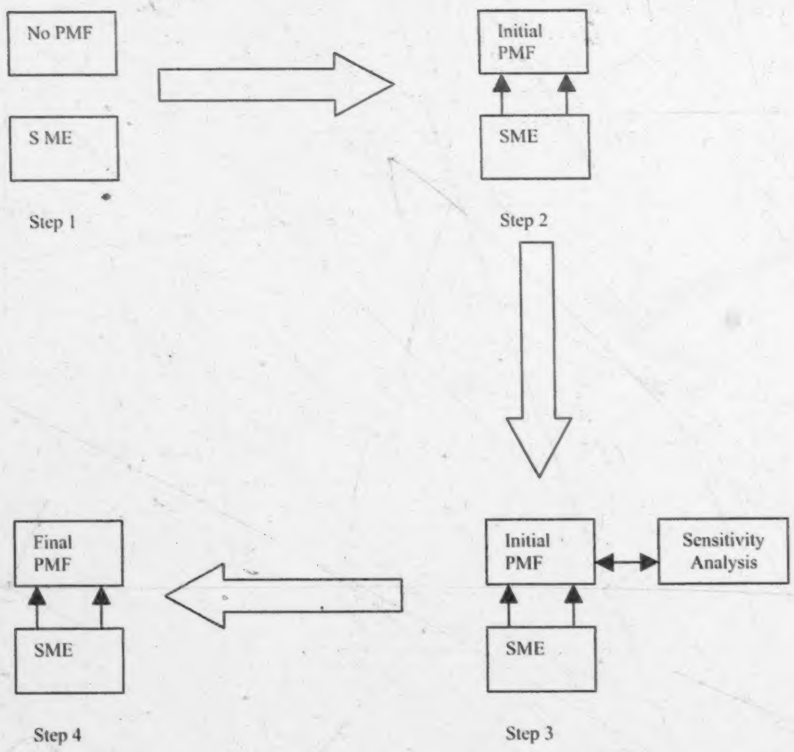

Theory
(Functionalist Approach)
Methodology
(System Dynamics)
Area of Application
(To Improve Business Performance)

Figure 3.1: Elements of research

3.3 Proposed Model of PMF based on the SD Approach

As was discussed previously, the system dynamics approach will be used to model an organization by modeling an organization's operations. There are four steps involved in achieving the performance measurement framework. Figure 3.2 shows the methodology for the proposed model exhibiting the different steps involved in developing a performance measurement framework. These are general in nature. However a specific example of each step is given in the case study described in chapter 4 and 5. As shown in the Figure 3.2:

- Step 1 starts with an assumption that our small business does not initially have PMF (Figure 3.3).


No PMF
S ME
Step 1
Initial PMF
SME
Step 2
Final PMF
SME
Step 4
Initial PMF
SME
Sensitivity Analysis
Step 3

PMF: Performance measurement framework
SME: Small and medium enetrprise

Figure 3.2: Methodology for the proposed model

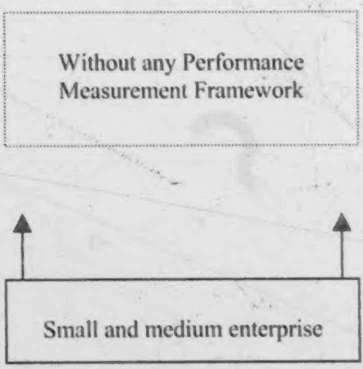

Without any Performance Measurement Framework
Small and medium enterprise

Figure 3.3: Initial state of performance measurement framework for a SME

- Step 2 involves modeling the whole company (by using a case study) and understanding the interrelationships among the subsystems. A model specific to any company will be developed by using system dynamics software. The initial performance measurement framework will include some performance measures from the literature and others specific to the model.
- Once the framework is complete, the Step 3 involves investigation of the behavior of the system by simulating the model. The interaction of the performance measures with the system will be examined by using the feedback loops. Therefore, the critical measures will be those that are sensitive to the performance of the company.
- Step 4 is achieving the final performance measurement framework for the company including measures that are critical to the performance of the company (from Step 3). The only difference between initial and final performance measurement frameworks is the number of measures present in the framework. The new framework has fewer performance measures than the initial framework. This new framework will support the company's performance management (Figure 3.4). Strategies can be made based on knowing the success factors that are critical for achieving the organizational vision or desired goals. The framework shown in Figure 3.4 works in two directions, i.e., one from the performance measurement framework to performance management, then to developing strategies and getting the desired results (the down-top approach); the other one from the vision or desired goals to making strategies enabling the performance-management framework to measure the critical success factors through performance measurement (the top-down approach).

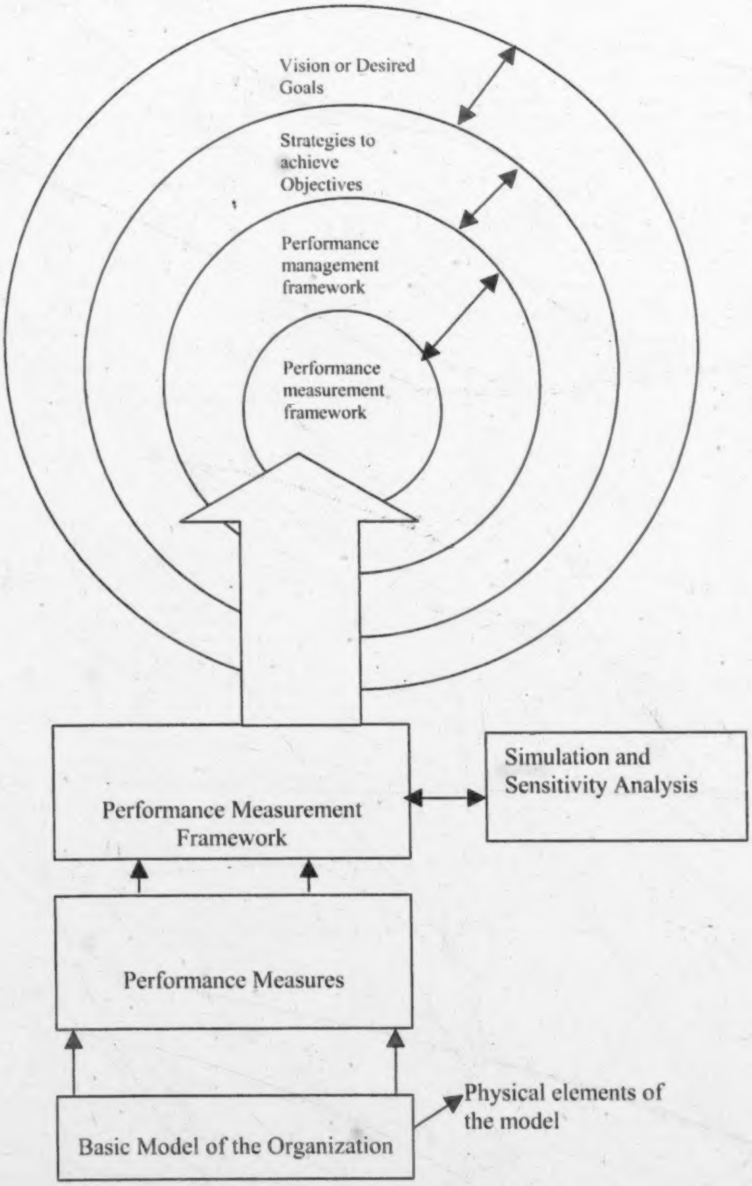

Vision or Desired Goals
Strategies to achieve Objectives
Performance management framework
Performance measurement framework
Simulation and Sensitivity Analysis
Performance Measurement Framework
Performance Measures
Basic Model of the Organization
Physical elements of the model

Figure 3.4: Proposed model of performance measurement based on the system dynamics approach

3.3.1 Possible Advantages of the Proposed Performance Measurement Framework

Using the proposed performance measurement framework based on the system dynamics approach has the following potential advantages:

- fewer number of performance measures to measure as compared to the other performance measurement framework;
- saves time and money for small businesses in terms of less documentation by measuring fewer performance measures;
- helps small businesses to spend their limited resources in critical areas, thus truly helping them in achieving their performance goals;
- provides quick feedback regarding performance;
- helps small businesses in making good strategies for the future; and

3.3.2 New Performance Measurement Framework Elements

Initially, a performance measurement framework is generated from a dynamic model of the company, as was discussed in the previous section. Performance measures present in the framework are of two types: end-result indicators and the input factors influencing these end results. The effect of input factors can be observed with the help of sensitivity analysis, which helps in understanding the interactions among the different sub-models of a company. These interactions are present in the form of feedback loops in the system. Therefore, the critical measures are those that are sensitive to the company's overall performance. These performance measures will make the new performance measurement framework for the company and can be sub-divided into two categories:

Critical End Result Indicators are the best indicators of the performance of the whole system. They are selected from the various end-result indicators present in the initial performance measurement framework generated from the dynamic model.

Critical Input Factors are those that interact with the system to generate end-result indicators. These input factors carry the information required by the system to produce the end results and should be measured constantly in order to ensure sustainable end results.

This new performance measurement framework consists of the measures identified by Neely (1995), who defined performance in terms of quality, time, price (cost), and flexibility. As well, the new framework also may include some traditional performance measures (e.g., total revenue, total selling) and some measures that may be of specific to interest of small businesses, such as the day's receivables (small businesses have very limited resources, so they need to be efficient in collecting the receivables). The performance measurement framework also includes some external factors like the state of economy because small businesses are very vulnerable to them, and must measure them in order to devise effective strategies for the future. Figure 3.5 shows the elements of our new performance measurement framework in terms of Neely's four categories, traditional measures, measures specific to small businesses, and external factors.

This new performance measurement will be used by the company to measure its performance and to develop strategies for achieving the company's desired goals.

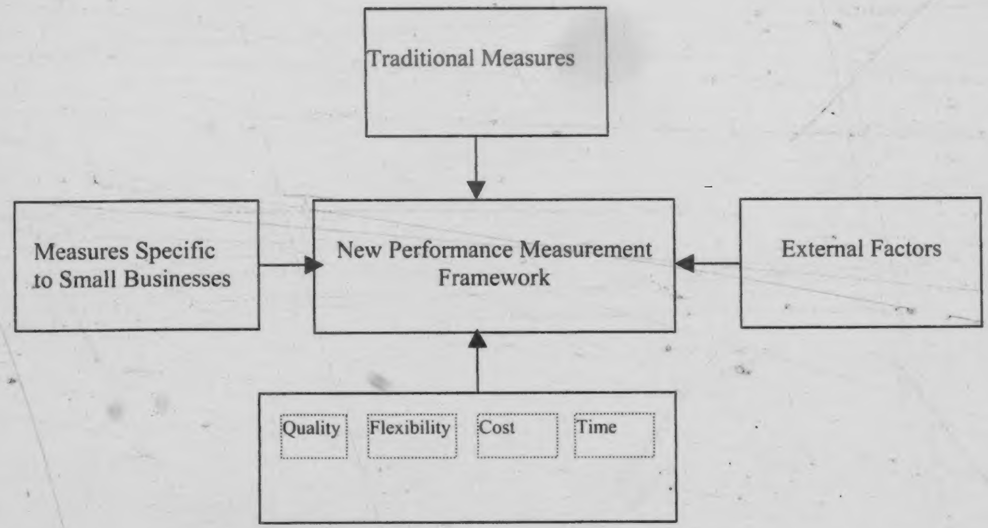

Traditional Measures
Measures Specific to Small Businesses
New Performance Measurement Framework
External Factors
Quality
Flexibility
Cost
Time

Figure 3.5: Elements of new performance measurement framework

CHAPTER 4

DYNAMIC MODEL OF PERFORMANCE MEASUREMENT FRAMEWORK FOR A SMALL AND MEDIUM SIZED MANUFACTURING COMPANY

4.1 Introduction

The development of a specific model for a performance measurement framework for a specific company is explained in this chapter. This model uses the functionalist approach discussed in the previous chapter.

4.2 Case Study of a SME

Objectives of Case Study:

- to develop a model of a typical manufacturing company by using the system dynamics approach,
- to develop a performance measurement framework based on the model of the company, and
- to identify the critical performance measures sensitive to the growth of the company.

4.2.1 Finding a company

A presentation was given to representatives of the National Research Council of Canada's Industrial Research Assistance Program (IRAP). They are responsible for providing knowledge-based, innovative assistance services to SMEs. IRAP identified two companies who were interested in the scope of the project.

The company selected is a valve manufacturer in Edmonton, Alberta that manufactures and sells valves to local oil and gas, chemical, and pulp and paper companies. The company is a small enterprise with 14 full-time employees. This company was selected because the aim of the research is to identify the critical performance measures specific to small and medium-sized businesses, and also because this company is typical of small businesses in Alberta.

4.3 Performance Measurement Framework for the Selected Company

The company does not have any formal performance measurement framework in place. Most literature is based on large companies and usually suggests that businesses should implement more performance measures than are actually possible for a small enterprise with limited resources. Table 4.1 lists the different types of performance measures suggested by Browne *et al.* (1997). This list covers almost all the aspects of any company and in general could be used by only stable and large businesses. Measuring all performance measures in the table requires lot of documentation and labour, which small businesses cannot afford. Small businesses need to measure only those performance measures that are critical to their performance. For that reason, we are using the functionalist approach. As was explained in the previous chapter, this approach, in order to achieve the desired results, sees the whole company as one system. The desired results for any company can be related to its total sales, total revenue, and total profit. Systems can be represented by models showing the interrelationships of the different parts within the system.

Table 4.1: Performance measures from literature (Adapted from Browne *et al*.., 1997)

Financial Measures

Measure	*Unit*
Sales (Turnover)	$
Fixed assets	$
Current assets	$
Purchased material cost	$
Other costs	$
Equity	$
Receivables	$
Current liabilities	$
Opening stock	$
Closing stock	$
External capital	$
Total liabilities	$
Profit from joint ventures	$

Product Development

Measure	*Unit*
Number of active products	Number
Product-related process engineering and design cost	$
Product research cost	$
Number of new products	Number
Total number of customer complaint-related design changes	Number
Engineering drawings change cost	$
Warranty costs for new products	$
Number of components recycled	Number
Total number of components produced	Number

Marketing and Sales

Total number of customers	Number
Marketing cost	$
Customer visits	Number
Number of on-time customer payments	Number
Products sold	Number
Number of customer suggestions	Number

Purchasing

Number of active suppliers	Number
Number of purchase orders	Number
Average material procurement lead time	Days
Number of on-time payments to suppliers	Number

Planning and Production

Number of customer orders	Number
Number of on-time outgoing deliveries	Number
Number of incomplete outgoing deliveries	Number
Average production and assembly lead time	Days
Total production cost	$
Inventory costs	$
Average cost of work in progress	$
Cost of scrap material	$
Re-work hours	Number

Personnel

Average number of employees .	Number
Total wages	$
Number of person-days lost due to absenteeism	Number
Number of new employees	Number
Overtime cost	$
Training and educational cost	$
Cost of incentive schemes	$

Other Measures

System downtime	Hours
Number of injuries	Number
Cost of preventative maintenance	$
Number of employee suggestions	Number
Machine downtime	Hours
Maximum available machine hours	Hours
Cost of improvement projects	$

Table 4.1 Continue

In order to develop a model for the selected company, information was required about how the company performs its different operations. A questionnaire was developed both to assist the development of the model of the company and to obtain data to verify /modify the model (see Appendix A). STELLA 6.0 (www.hpsinc.com) software facilitated the process of developing a computer model of the company by using the information gathered through the questionnaire.

4.4 Performance Measurement Framework using a System Dynamics Approach

The dynamic model and performance measurement framework for the company (Figure 4.1) consists of:

- a computer model of the company, developing the interrelationships among its different parts. The model will be developed in the next section;
- an initial performance measurement framework generated through the model, including simple performance measures (as discussed in Chapter 2) present in the model. These performance measures can be divided into two categories: end-result indicators and input factors influencing end-result indicators. Initial performance measurement framework is discussed in detail in section 4.4.2; and
- the company's final performance measurement framework determined by sensitivity analysis. Chapter five discusses sensitivity analysis and the company's final performance measurement framework in detail.

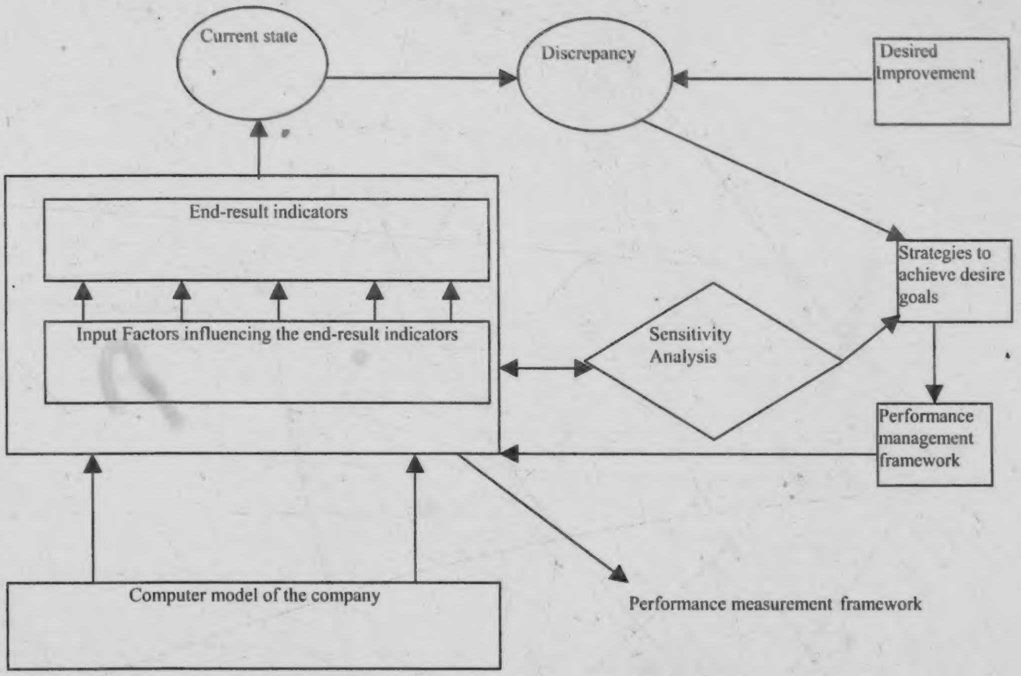

Current state
Discrepancy
Desired Improvement
End-result indicators
Input Factors influencing the end-result indicators
Strategies to achieve desire goals
Sensitivity Analysis
Performance management framework
Computer model of the company
Performance measurement framework

Figure 4.1: Performance measurement framework based on system dynamics approach

4.4.1 The Computer Model of the Company

A computer model is a representation of a company's processes and their interrelationships. A model was developed through the questionnaire and implemented via the Stella software. Figure 4.2 represents the Stella representation of the company's model showing the interactions among different sub-models. Each sub-model is described in following sections. The company's model consisted of:

- the ordering sector which calculates the number of orders for the company produces;
- production sectors for each of these products e.g. "P.L. ANSI 150" is a production sector for ANSI 150;
- the machining sector which calculates the "machining" cost that the company pays to its subcontractors for supplying machined parts;

- a raw material cost sector which calculates the raw material costs for the company which it pays to their suppliers;
- a financial sector which calculates the revenue for the company generated by selling each kind of product;
- and, the cash flow sector calculates the cash position for the company.

Once the model is validated against company's actual performance, a performance measurement framework then can be generated from the model of the company as mentioned in Chapter one. The next section explains the development of the computer model for the selected company and its validation.

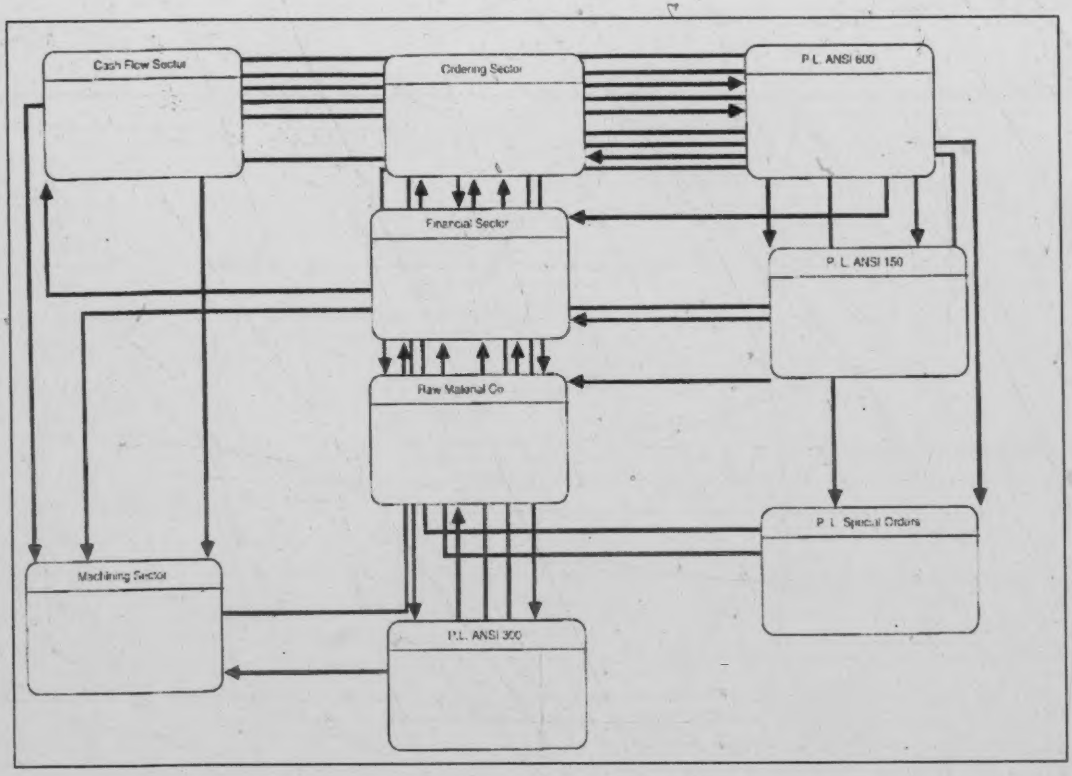

Cash Flow Sector
Ordering Sector
P.L. ANSI 600
Financial Sector
P.L. ANSI 150
Raw Material Co
P.L. Special Orders
Machining Sector
P.L. ANSI 300

Figure 4.2: Computer model of the company

4.4.1.1 Company Features to be Modeled

The company manufactures four types of valves under the American National Standards Institution (ANSI) standards:

- ANSI 150

The ANSI 150 type includes valves with diameter sizes from 3 inches to 72 inches, with a pressure limit up to 20 kPa.

- ANSI 300

The ANSI 300 type includes valves with diameter sizes from 3 inches to 42 inches, with a pressure limit up to 50 kPa.

- ANSI 600

The ANSI 600 type includes valves with diameter sizes from 6 inches to 24 inches, with a pressure limit up to 100 kPa.

- Special Orders

Special orders differ from orders for the standard products because these orders are for valves that do not conform to the above specifications. For example a valve with diameter size of 3 inches with a pressure limit of 100 kPa considers being a special order. Company also provides servicing and repairing of the valves. We have not included these factors and the revenue generated by these in our model because the scope of this research is just limited to new orders.

Figure 4.3 shows the various parts of a simple valve. All four types of products are made of the same components shown in the figure.

A- Packing flange nuts

B- Gasket seal

C- Body

D- Steel shaft

E- Actuator mounting pad

F- Seat

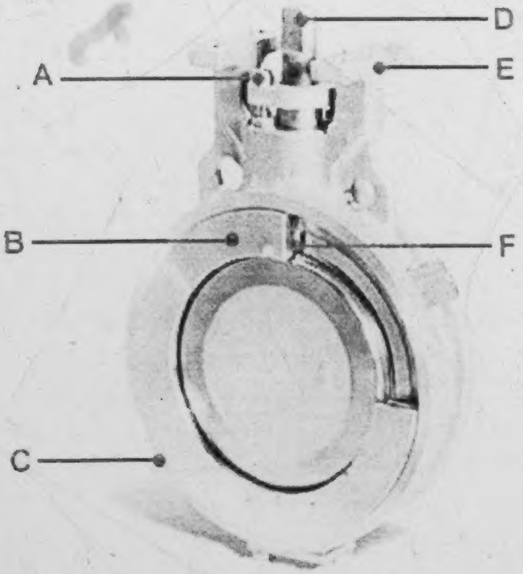


Figure 4.3: Components of a simple valve

The assembling of products follows the simple flow as shown in the Figure 4.4.

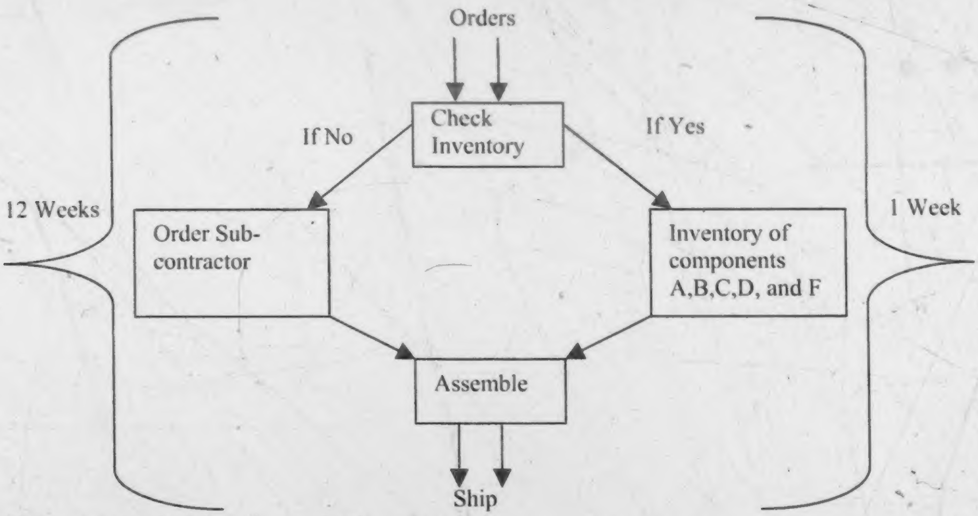

Orders
Check Inventory
If No
If Yes
12 Weeks
Order Sub-contractor
Inventory of components A,B,C,D, and F
1 Week
Assemble
Ship

Figure 4.4: Logical flow for production of products

The inventory of the machined parts (A, B, C, D, and F) is checked after receiving orders from the distributors, if the company has sufficient inventory the orders will be assembled within the specified delivery time (1 Week), but if the inventory is not sufficient- in other words if the inventory reaches to a specific lower limit set by the company and cash is available, the company has to order its sub-contractors to supply the machined parts. The orders will then be assembled after receiving the machined parts from the sub-contractors (12 Weeks on average).

The following section describes how each component of the model is manufactured and assembled. An understanding of the manufacturing and assembling processes is required to create the overall business model. The model consists of different sub-models representing the different operations of the company (summarized previously on Figure 4.2). The model consists of the following sub-models:

- ordering sub-model
- production sub-model
- financial sub-model
- cash flow sub-model

4.4.1.2 Ordering Sub-Model

According to the data collected through the questionnaire and interviews, the company receives orders from different distributors, who send purchase orders for different types of valves. Looking into the purchase orders data it was deduced that at present the company forecasts that the orders for any next month to be:

- ANSI 150 (60 % of the last month's orders),
- ANSI 300 (6 % of the last month's orders),
- ANSI 600 (26% of the last month's orders), and
- Special Orders (8% of the last month's orders).

Figure 4.5 shows the ordering sub-model for the company; according to the figure, ("ORDERS LAST MONTH" (top center of the Figure 4.5) is the total number of orders received last month). The company begins forecasting with the orders for the next month as a percentage of the previous month's orders, however the actual ordering rate also depends on three other external factors that can increase or decrease the amount of orders. They are summarized below and discussed quantitatively in the following sections.

Price justification of the product (Price factor, lower left in the Figure 4.5): In a competitive environment, a small increase in the price of the product may greatly reduce the number of orders.

Price Factor: The price factor shows how a change in price influences the orders. As the market is very sensitive to the price, the company assumes (according to the information gathered through questionnaires) that a 10% increase in price will result in 20% fewer orders.

Market trends for the product (Economy factor in the Figure 4.5): The economy in the end-user's sector will also affect the ordering rate. Good economic conditions will result in more orders and vice versa. Economy factor shows that trend for the company.

Economy Factor: Alberta has had the fastest-growing economy in Canada over the past ten years, with the annual real rate of growth averaging 4.5 percent. The energy sector contributes a large portion of this growth. $50 billion of new investment will increase the production of oil from 320,000 bbl/day (in 2000) to 1.7 million bbl/day (in 2010) (Alberta Government, 2002). Apart from the investments, the growth of the oil sector also depends upon the price of oil. Too high a price will result in a low production of oil from oil producers as no one wants to buy at a high price.

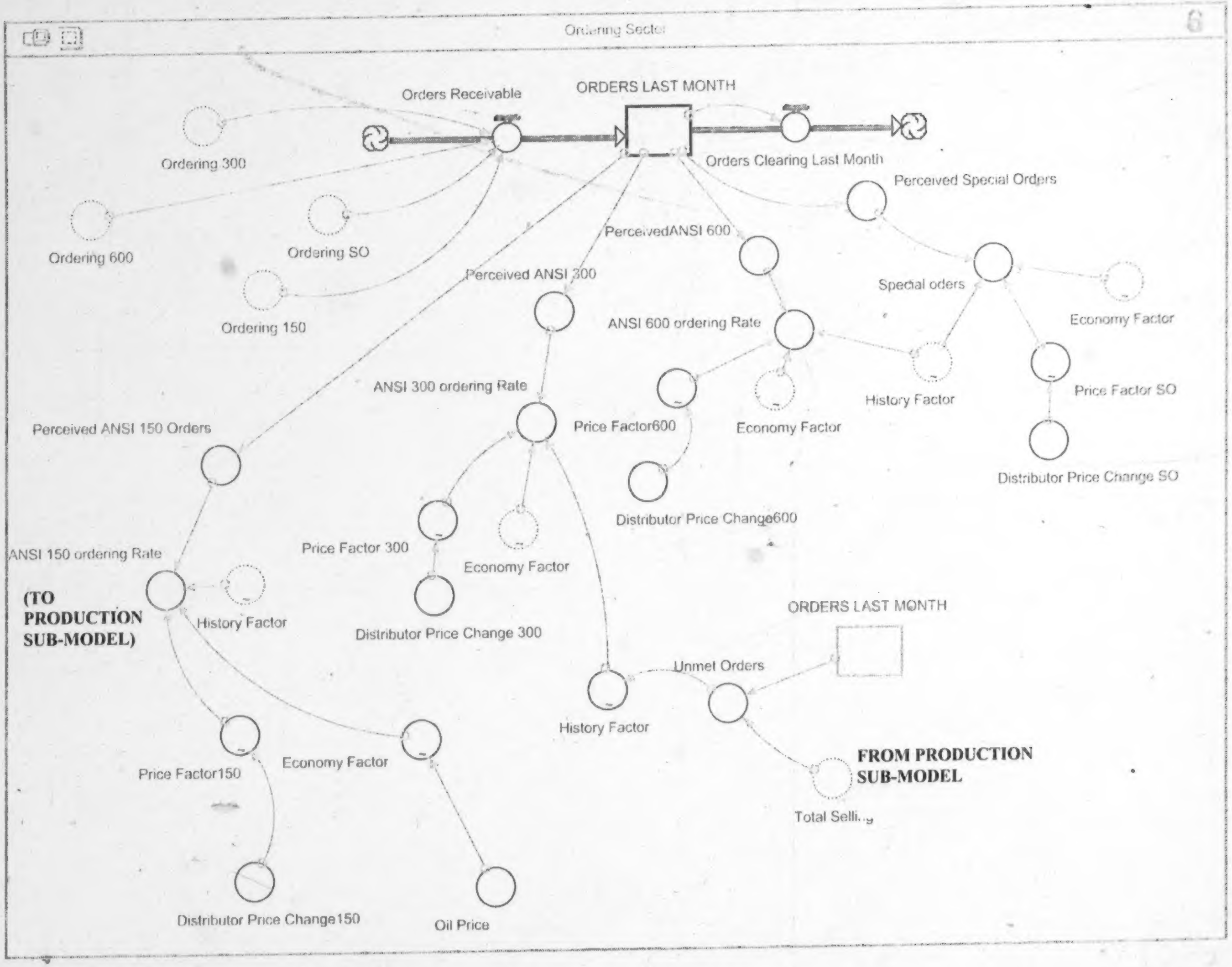

Ordering Sector
Orders Receivable
ORDERS LAST MONTH
Orders Clearing Last Month
Ordering 300
Ordering 600
Ordering SO
Ordering 150
Perceived Special Orders
PerceivedANSI 600
Perceived ANSI 300
Special oders
Economy Factor
ANSI 600 ordering Rate
ANSI 300 ordering Rate
History Factor
Price Factor SO
Price Factor600
Economy Factor
Perceived ANSI 150 Orders
Distributor Price Change SO
Distributor Price Change600
Price Factor 300
Economy Factor
ANSI 150 ordering Rate
(TO PRODUCTION SUB-MODEL)
History Factor
Distributor Price Change 300
ORDERS LAST MONTH
Unmet Orders
History Factor
FROM PRODUCTION SUB-MODEL
Total Selli..g
Price Factor150
Economy Factor
Distributor Price Change150
Oil Price

Figure 4.5: Ordering sub-model for the company

Too low an oil price will result in shutting down the oil-production plants, as producing products at a low price is not cost-effective. In other words, low prices hamper much-needed investments while high prices jeopardize the world economy. Therefore, the price of oil plays a significant role in the growth of the oil sector. This growth directly affects the company's orders. An increase in oil production capacity, and in planned maintenance of the production plants will ensure more sales for the company. The price of oil is a good indicator of the growth and economy of the oil sector and, hence, of the company's growth as well. The Figure 4.6 below shows the effect of oil price on the company's orders as discussed before.

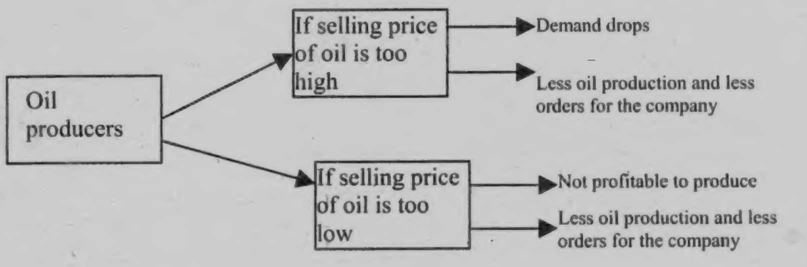

Oil producers
If selling price of oil is too high
Demand drops
Less oil production and less orders for the company
If selling price of oil is too low
Not profitable to produce
Less oil production and less orders for the company

Figure 4.6: Effect of oil price on the company's orders

Figure 4.7 shows the trend in the yearly average price of oil, and Figure 4.8 shows the yearly revenue of the company. The company's revenue trend shows a significant increase during 1999, when the average yearly price of oil was $23.33 per barrel, as compared to $11.91 per barrel for 1998. Thus a price of around $20-25 per barrel results in more orders for the company. The price of oil was $27.4 per barrel in 2000, and the company's revenue decreased. By the end of 2001, the price of oil was $25.6 per barrel, and once again, the company's revenue increased.

It can be assumed that the hike in revenue for the year 1999 resulted from a tremendous change in the oil price. As was discussed above, a too low price of oil will result in shutting down the refineries. According to Gautreau (2001), oil producers were battered by the approximately $10 per barrel oil price in 1998 when the Asian financial crisis spread to other parts of the world. However, in 1999, after the price of oil was again high enough for the oil producers to get back in business, the company's revenue significantly increased. A petroleum engineer of an oil company commented, " As long as oil prices remain above $20 per barrel, producers for the most part could stay profitable" (Gautreau, 2001). Therefore, the sudden hike in the company's revenue for 1999 resulted from the oil producers' return to business.

The above discussion shows that the price of oil is a good indicator of the state of the oil sector and also of the company, as the oil sector is a major end user of the company's products. The company assumes that if the price of oil stays at $22 per barrel, given Alberta's expanding economy, the company's orders will increase by 10 percent each year. In other words, the company's orders (or the company's economy factor) are heavily based on the price of oil (Figure 4.9).

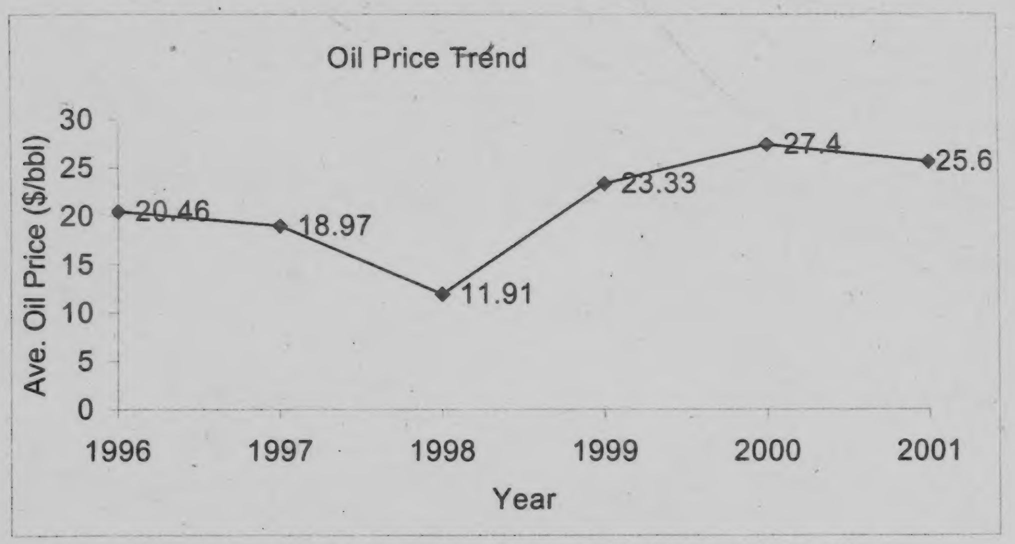


Figure 4.7: Average yearly price of oil (http://www.ioga.com//special/crudeoil_Hist.htm)

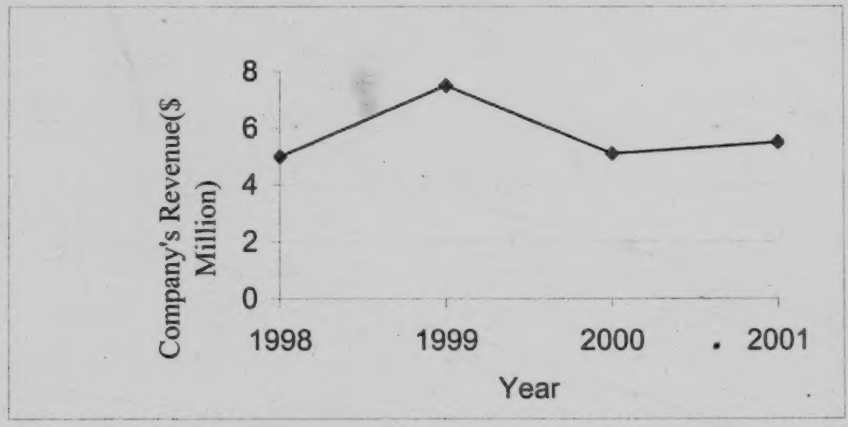


Figure 4.8: Company's revenue per year

Figure 4.9 shows the relationship between the price of oil and the company's economy factor. The historical price trends of the oil show that a price range from $15 to $25 per barrel is the most favorable range for the oil producers to be profitable and for the company to get more orders.

The figure 4.9 indicates that a price of oil of less than $15 per barrel will result in a factor of less than one, reducing the number of orders for the company, as will an oil price is more than $25 per barrel. Since this is an initial approach, we haven't analyzed this concept in terms of price elasticity.

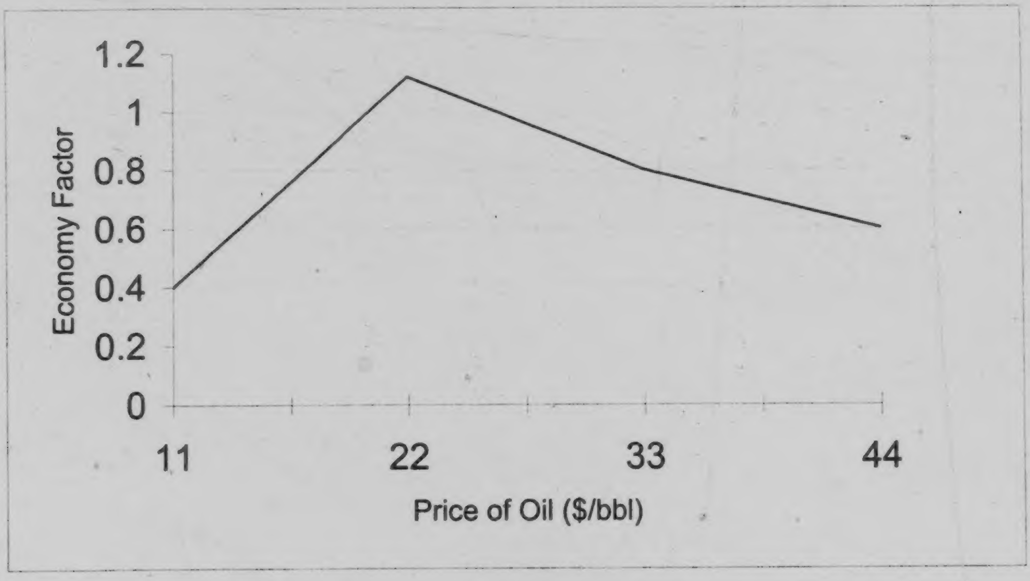


Figure 4.9: Relationship between the price of oil and economy factor for the company

Gaining the trust of existing customers (History factor in Figure 4.5): Building trust, confidence, and loyalty with the existing customers is very important for the company for two reasons:

- If the existing customers believe that the company is reliable in delivering quality products, they will continue to buy from the company. Attracting new customers always costs more than keeping old ones.
- Poor quality products and services, on the other hand, lead to customer dissatisfaction in the form of complaints, cancellation of orders and unfavorable word of mouth.

History Factor: The history factor shows the effect of unmet orders. A high level of unmet orders will likely result in fewer orders in the future. Unmet orders are the number of orders which the company was not able to fill because of the non-availability of the finished raw material. When a company has a large number of unmet orders, the customers will assume that company is not reliable in delivering its products and will order less in the future, on the other hand if a company is reliable in delivering its products, the customers will order more in the future.

The graph below (Figure 4.10) shows the relationship between the unmet orders and history factor. The customer will order 1.1 times more if the unmet orders are zero.

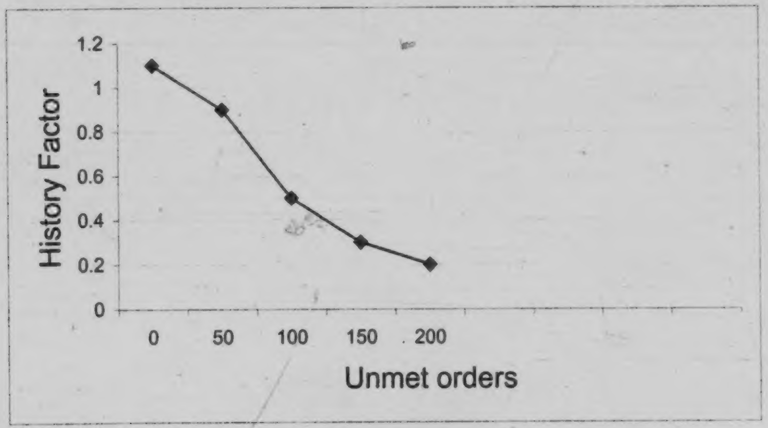


Figure 4.10: Relationship between unmet orders and history factor

These factors affect all types of the company's orders. According to the Figure 4.5,

Ordering Rate = Forecasted orders (as percentage of the previous month) *Price factor * Economy factor *History factor

The above-mentioned factors are discussed quantitatively below.

Example Calculations

Therefore, the company calculates the forecasted orders for next month by the equation described before. For example if the ANSI 150 is 60% of the total last month orders (let say 120), price of product remains the same (price factor is 1), economy is good (lets say remains the same 1.1), and history factor is also 1.1 as company meet all the orders. The next month orders according to ordering equation would be:

Ordering Rate for ANSI 150= 72* 1 * 1.1 * 1.1 = 87 (units per month)

4.4.1.3 Production Sub-Model

The company does not manufacture the different components of the valves because a operating manufacturing facility would not be cost-effective for a company of this size.

The company subcontracts the components to different machine shops (subcontractors) and then assembles the components. The company has 10 subcontractors, one of which receives 50 % of all orders. The subcontractors are the same for all products. Every subcontractor can do the machining of parts A to F, as shown above in the Figure 4.2. Having several subcontractors reduces company's dependability on one major subcontractor, and the company can easily manage its high demand of finished parts by splitting among various subcontractors. According to the data collected, all contractors take 12 weeks on average to deliver the machined parts, except for the special orders. Therefore, the company maintains an inventory of machined parts to cater to customers. Figure 4.11 shows the production sub-model for ANSI 150 type; the production sub-models for all other types are the same (see Appendix B). Based on interviews and the questionnaire, the production sub-model of the company was developed to represent the actual production process.

- As shown in the Figure 4.11 the "ANSI 150 ordering rate" is obtained from the ordering sub-model (shown Figure 4.5). This fills the stock of orders shown as "ORDERS 150" in the Figure 4.5 providing a backlog. The backlog or stock of orders is generally assembled from the machined parts in the inventory (including each component of a valve), which is "MC MATERIAL INVENTORY 150" stock in the Figure 4.11.
- Assembling is required to produce the orders and the "Assembling 150" rate in the Figure 4.10 depends on the number of workers available and their productivity.

  Assembling Rate = Productivity * No. of Workers

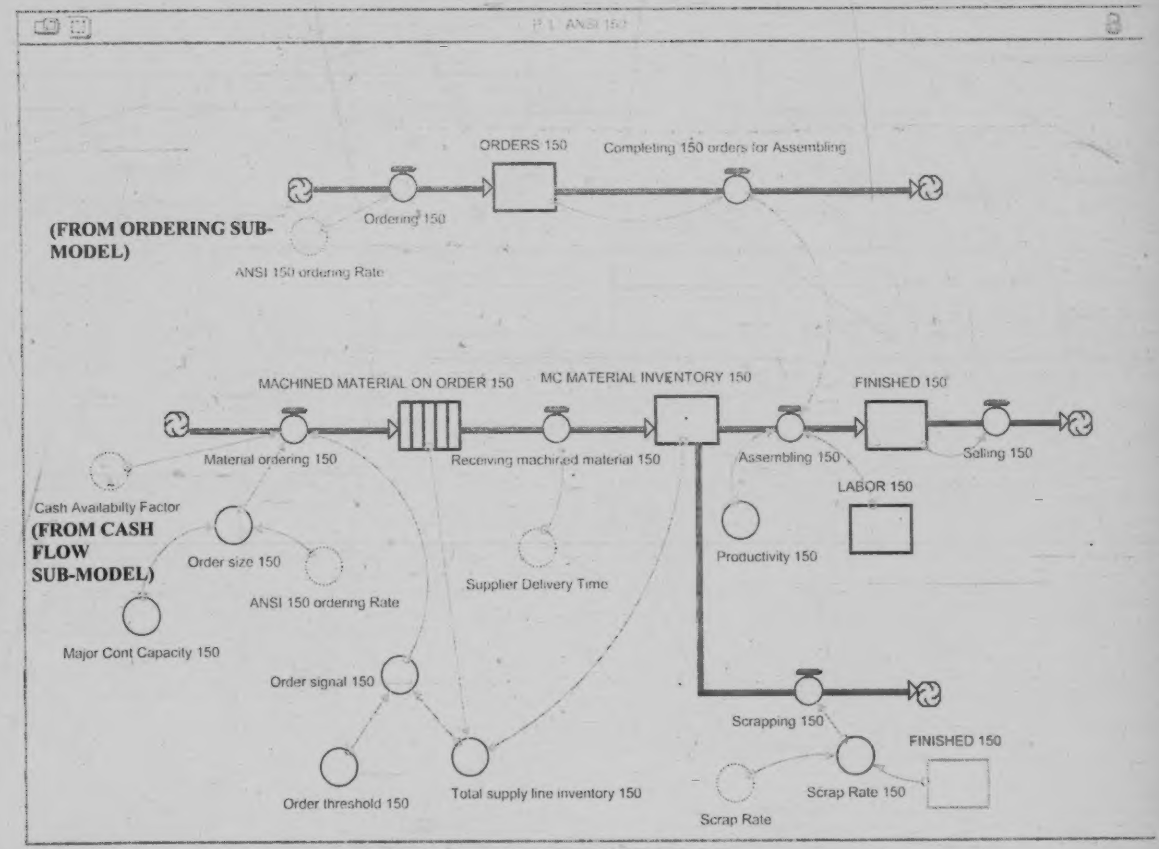

ORDERS 150
Completing 150 orders for Assembling
Ordering 150
(FROM ORDERING SUB-MODEL)
ANSI 150 ordering Rate
MACHINED MATERIAL ON ORDER 150
MC MATERIAL INVENTORY 150
FINISHED 150
Material ordering 150
Receiving machined material 150
Assembling 150
Selling 150
LABOR 150
Cash Availabilty Factor
(FROM CASH FLOW SUB-MODEL)
Order size 150
ANSI 150 ordering Rate
Productivity 150
Supplier Delivery Time
Major Cont Capacity 150
Order signal 150
Scrapping 150
FINISHED 150
Order threshold 150
Total supply line inventory 150
Scrap Rate 150
Scrap Rate

Figure 4.11: Production sub-model for ANSI 150 type

"Productivity" is the number of average valves assembled by a worker in a month.

- These assembled parts provide the finished products (FINISHED 150 stock in Figure 4.11) ready to be delivered (or sold) to the customer.
- "Scrapping 150" in the Figure 4.11 calculates errors in assembling or scrapping (according to the data collected company has a scrap rate of 1% of the finished products). Thus decreases the number of products in stock (MC MATERIAL INVENTORY 150 stock in Figure 4.11), so a higher scrap rate results in smaller inventory of machined material, i.e., in a decrease in the assembling rate.

- While an order is being filled from inventory the subcontractor receives an order from the company to refill the inventory as long as cash is available. In order to maintain the inventory of machined products (components of a valve), the company orders from its subcontractors to supply the machined material ("Receiving machined material 150" in the Figure 4.11). Ordering machined material from the subcontractors depends on two factors:
    - The cash availability factor means that company places orders only when cash is available. The cash flow model (see cash flow model, figure 4.13) shows the cash position of the company.
    - The order size factor involves the size of the order to be delivered by the subcontractors. As the major subcontractor gets 50 % of the total orders, the order size heavily depends on the major contractor's capacity. If this subcontractor cannot provide the company with enough machined parts, its inventory and hence, its sales will decrease.

Therefore, Material ordering = Cash availability factor x Order size

For example if the order size for ANSI 150 is 200 and the cash availability factor is 0.9, the material ordering would be:

Material Ordering for ANSI 150 = 200 * 0.9 = 180

That means company get fewer machined parts from the subcontractor for its inventory and as a result sales will also be decreased.

4.4.1.4 Financial Sub-Model

The Company generates its revenue by selling the valves (i.e. from production sub-model). Figure 4.12 shows how the company calculates its total revenue, total cost and profit. The following sub-sections discuss how each of these is calculated in the model.

4.4.1.4.1 Revenue

Revenue is generated by each type of valve=Selling Price * Number of Valves sold [1]

The average amounts that a distributor pays the company for the products are:

- $1500 for ANSI 150
- $2500 for ANSI 300
- $6500 for ANSI 600, and
- $10000 for a Special Order

The production model for each type will give the number of valves sold (see Figure 4.11).

Total revenue is the sum of revenues generated by each type of valve.

Total Revenue= Revenue from ANSI 150 + Revenue from ANSI 300 + Revenue from ANSI 600 + Revenue from Special orders [2]

4.4.1.4.2 Total Cost

Total cost shows the cost of producing the products.

Total cost is calculated as follows:

Total Cost = (1+Overhead Fraction) * (Labour Cost +Total Machining Cost +Total Raw Material Cost) [3]

- Overhead fraction is the fraction of the total cost allocated to overhead (management) costs.

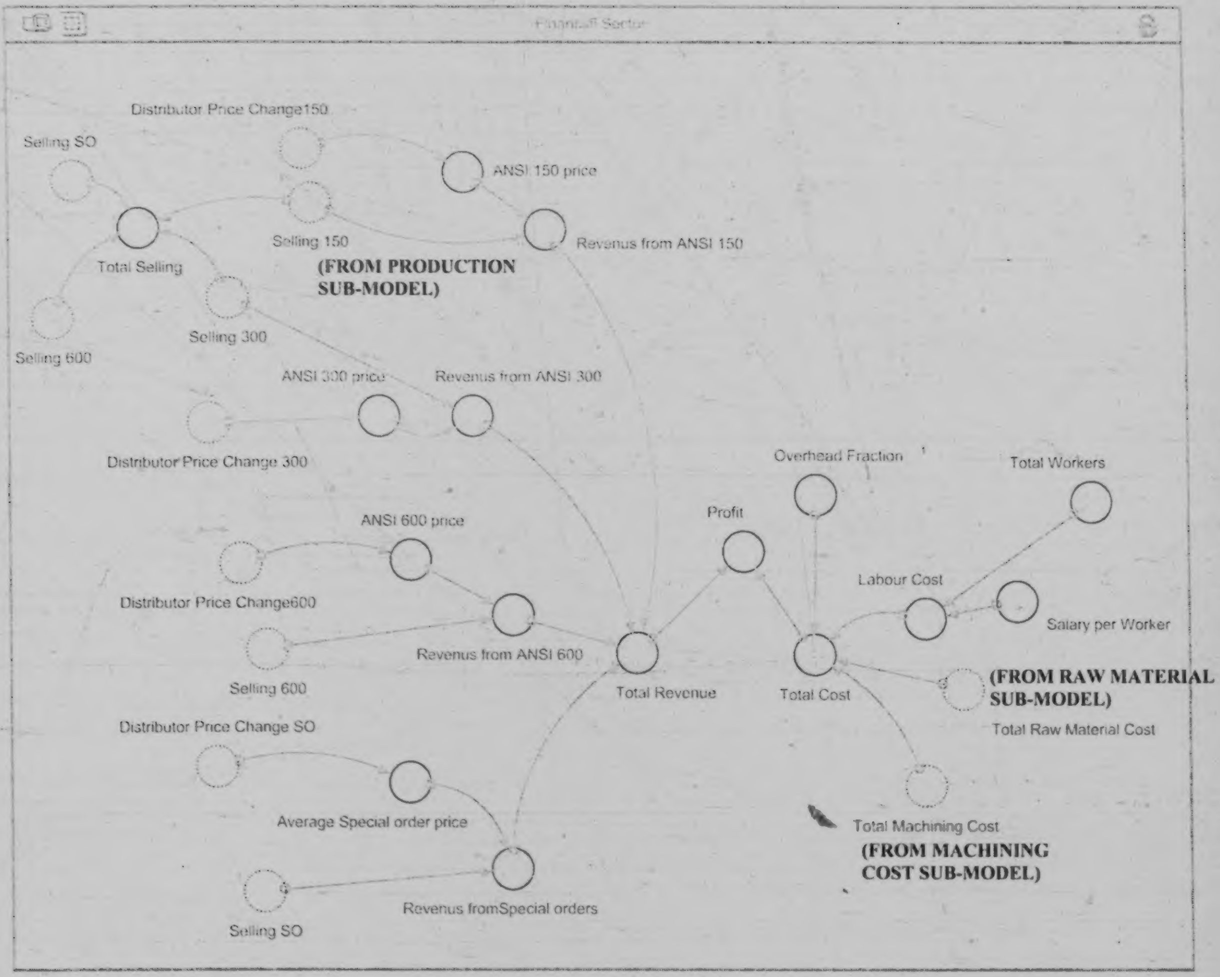

Financial Sector
Distributor Price Change150
Selling SO
ANSI 150 price
Total Selling
Selling 150
Revenus from ANSI 150
(FROM PRODUCTION SUB-MODEL)
Selling 600
Selling 300
ANSI 300 price
Revenus from ANSI 300
Distributor Price Change 300
Overhead Fraction
Total Workers
Profit
ANSI 600 price
Labour Cost
Distributor Price Change600
Salary per Worker
Revenus from ANSI 600
Selling 600
Total Revenue
Total Cost
(FROM RAW MATERIAL SUB-MODEL)
Total Raw Material Cost
Distributor Price Change SO
Average Special order price
Total Machining Cost
(FROM MACHINING COST SUB-MODEL)
Revenus fromSpecial orders
Selling SO

Figure 4.12: Financial sub-model for the company

- Labor cost = Average salary per employee (Including benefits) x Total number of employees [4]
    - Average salary for an employee is $3000 per month.
    - Company has 14 full-time employees.
- Machining cost is the amount that company pays to its subcontractors for providing the machined parts and is calculated as:

Total machining cost = Sum of the Material Ordered from subcontractors for each type of product * Machining cost/ valve/each type [5]

The machining cost for each valve is 35% of the distributor price (see Machining model in Appendix B).

- Raw material cost is the amount that company pays its supplier to deliver the raw material and is calculated as:

Total raw material cost = Sum of the Material ordering from subcontractors for each type of product * Raw material cost/ valve/each type [6]

The raw material cost of each valve is 20% of the distributor price (see Raw material model in Appendix B).

4.4.1.4.3 Profit

Profit is calculated by subtracting the total monthly cost from the total monthly revenue.

Profit = Total Revenue – Total Cost [7]

For example, the company generates total revenue of $500,000 per month by selling its various products and the total cost per month is $ 300,000, the profit for the company would be $200,000 per month.

This amount is calculated monthly. The effect of this profit will be on the cash reserves, as the revenue will turn into cash after a certain amount of time (The days of sales outstanding or days of receivables), and the total cost will be paid from the cash after a certain amount of time, i.e., days of payables.

4.4.1.5 Sub-Model of Cash Flow from Operations

The cash-flow sub-model (Figure 4.13) calculates the company's cash-in-hand position. The total revenue from the financial sub model fills the stock of receivables. The stock of receivables in the model (Figure 4.13) determines the amount of money that the company has to collect from its customers. These receivables turn into cash after an average collection period of time called "days sales outstanding" (DSO). The "cash-in valve" in the model turns the receivables into cash after a specified number of days sales outstanding. The company's DSO was calculated from its balance sheet as:

DSO= Receivables / Sales/360 [8]

DSO= \$570,557.72 / \$4,694,384.77 / 360 = 44 days (We used 45 days in the base runs because of the ease of incorporating this in the model)

DSO is a measure of how effective a company is in getting its customers to pay. Especially for small and medium businesses, DSO is one of the critical factors to consider because it can reduce the company's short-term borrowing (Flynn, 2001).

The cash stock in Figure 4.13 represents the amount of money available to the company to pay its expenses. The company's cash stock includes the cash generated from selling and from other sources like short-term borrowing. The cash stock does not include other factors affecting the cash, such as

- prepaid expenses,
- taxes on taxable income'

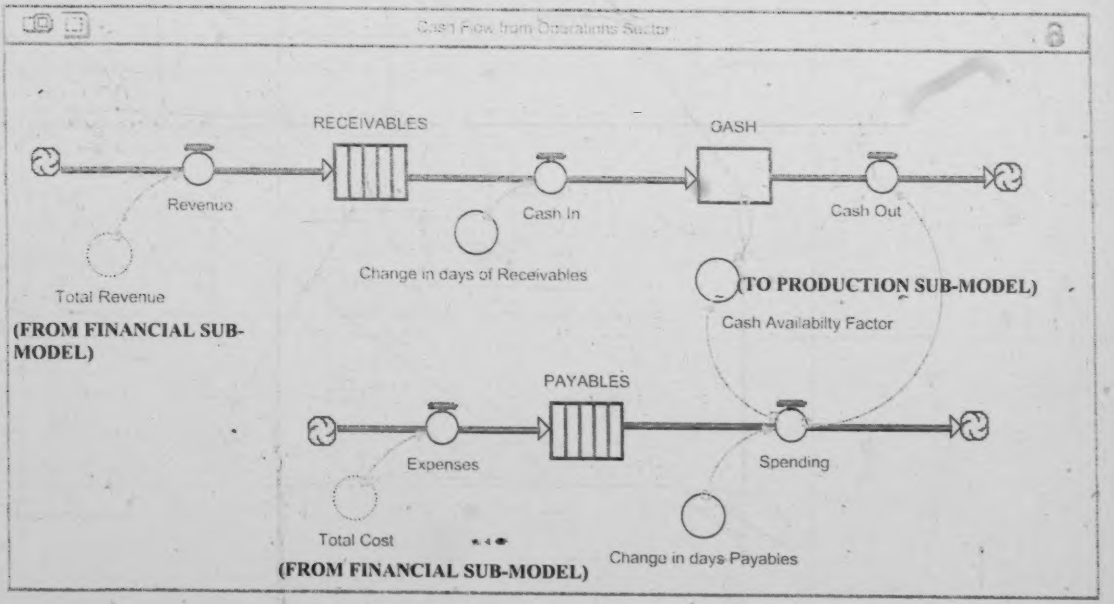

Cash Flow from Operations Sector
RECEIVABLES
CASH
Revenue
Cash In
Cash Out
Total Revenue
Change in days of Receivables
(TO PRODUCTION SUB-MODEL)
Cash Availabilty Factor
(FROM FINANCIAL SUB-MODEL)
PAYABLES
Expenses
Spending
Total Cost
Change in days Payables
(FROM FINANCIAL SUB-MODEL)

Figure 4.13: Cash-flow sub-model for the company

- inventory, and
- financing and investing activities.

Therefore, the cash calculated in the model is only the cash received from the operating activities.

The total cost in the financial sub-model fills the stock of payables, and the company pays its payables after 30 days. Payables (or total expenses) include salaries and the amount due to suppliers for raw material and machining. The spending valve in the model releases an amount of payables after a specified time and will drain the cash stock in terms of cash out.

The cash availability factor in the model is calculated as:

Cash-availability factor = Cash / Spending [9]

This factor determines the financial ability of the company to pays its suppliers and employees. A factor of less than one means that a company has more expenses than the cash it has on hand and is not able to order more from its suppliers. Therefore, the company can run out of business because of the unavailability of cash.

4.4.1.6 System Performance

The growth of the company is related to improving its different processes. In order to improve processes, their interrelationships must be understood. In other words, the company must be viewed as one complete system. The next section discusses how the model calculates different performance parameters of the system.

4.4.1.7 Whole System Sample Calculation

The development of individual sub-model was discussed before; now this section illustrates a sample calculation of how the model calculates the different parameters of the model using the actual data. As shown in the Figure 4.14, the ordering sub-model calculates the orders to be assembled by the production sub-model depending upon the machined material inventory available. "Total Selling" from the production sub-model goes to the financial sub-model to calculate total revenue.

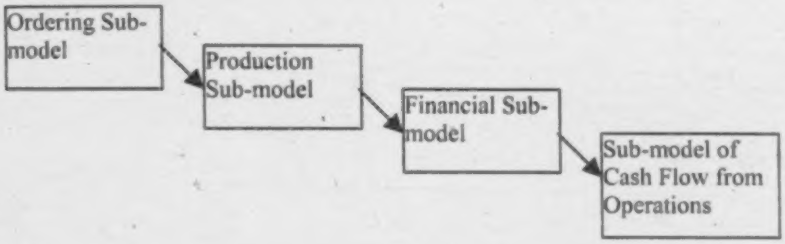


Figure 4.14: Data flow within the sub-models of the company

The results are done for July 2001 and are summarized in Table 4.2 after all the calculations. The model also calculates other values of the parameters shown in the tables called "Debug" tables in Appendix C. The Stella software allows the calculated parameters to be representing in the forms of graphs or debug tables.

The orders receivable for the month of July 2001= Ordering 150 + Ordering 300 +
Ordering 600 + Special orders

Ordering 150 = NORMAL (ANSI_150_ordering_Rate, 15,150), which will give a random number from the normal distribution.

ANSI 150 ordering Rate = Perceived ANSI 150 Orders *Economy Factor *Price Factor150* History Factor

Perceived ANSI 150 Orders is calculated from the "ORDERS LAST MONTH" stock. The company perceives that for ANSI 150, 60 percent of the last month's orders would be.

Perceived ANSI 150 = LAST MONTH ORDER BOOK * 0.6
= 120 * 0.6
= 72

The economy factor is 1.01; this value comes from the relationship of price of the oil and the orders for the company. For example in 2001, the average price of oil was $25.6 per barrel, which increased the company's orders by one percent.

The price factor is 1, as the price of the product for the base run does not change. The history factor is 1.1, as the company fulfilled all of the last month's orders and does not have any unmet orders.

Therefore,

ANSI 150 ordering Rate = 72* 1.01* 1* 1.1

= 80

Total selling for the month of July 2001= Selling 150 + Selling 300 + Selling 600 + Selling Special orders (SO)

Total Revenue for the month of July 2001 = Revenue from 150 + Revenue from 300 + Revenue from 600 + Revenue from Special orde

= $236,674

4.4.1.8 Validation of the Model

Forrester (1961) proposed various methods for the validation of the model. One of them involves giving minimum or maximum values to the variables to determine if the model captures the expected behavior. For example, giving the order size of machined material a value equal to zero should result in draining off the initial stock of machined material available. This test was run and the model's behavior resulted in draining off the initial stock of machined material when given an order size of machined material a value equal to zero. Hence the model captured the expected behavior. Due to very common problem in small businesses is the lack of collection of data. This is exemplified in the case study company with the availability of only three months data used for validation. Therefore, when confirming the model against the data provided one should take that into account.

The other method is to compare the model's predicted behavior with the historical data. Only three months (July to September 2001) of historical (i.e., Table 4.3a, 4.3b & 4.3 c) data was available from the company. The historical data included total revenue, and total selling for the month. Table 4.2 below shows an ***initial*** comparison between the predicted and real values.

	July 2001			August 2001			September 2001		
	Predicted	Real (ANSI + Special and Others)	Diff	Predicted	Real (ANSI + Special and Others)	Diff	Predicted	Real (ANSI + Special and Others)	Diff
Total Revenue	$236,674	$404,529	41%	$329,825	$516,288	36%	$246,885	$307,798	20%
Total Selling	79	110	28%	110	80	-38%	85	54	-57%

Table 4.2: ***Initial*** differences between the predicted and real values

The predicted and real values for the month July 2001 differ for the following reasons:

- The real revenue of the month July 2001 also includes a specific revenue ($77,243) which came from the selling of more than just valves. It included selling the drawings, gears, and various components. The model does not include this type of selling (Table 4.2)
- The real revenue includes revenue from the order long in the past. The predicted revenue for July does not include any revenue from the special orders, but the real revenue for July includes some revenue ($81,072) from them (Table 4.3).

If we deduct these two factors from the real revenue the revenue would be $246,215, and the difference then would be around 4 percent. If we calculate the real average prices of each the valve type for three months as shown in the tables 4.3a to 4.3c, it is evident that the real average prices for the month July are very close to the distributor prices assumed in the model i.e. the real average price for ANSI 150 is $1469 as compare to the assumed $1500, for ANSI 300 it is $2001 as compared to $2500, for ANSI 600 it is $ 4974 as compare to $6500 and for special orders is $9008 as compare to $10,000 (Table 4.3a). Therefore, the difference is for this month is less. Real average prices for the month August are very higher (Table 4.3b), i.e. real average price for ANSI 150 is $1799 as compare to assumed $1500, real average price for ANSI 300 is $5039 as compare to assumed $2500, real average price for ANSI 600 is $11,401 as compare to assumed $6500 and the real average price for special orders is $14,740.5 as compare to assumed $10,000. This real average prices are higher because of the fact the customer can ask for additional features apart from the base product, for example customer may ask for double flanges that will cost more. Average real prices for each product are also higher for the month September (ANSI 150 is $1990, ANSI 300 is $2772.5, and Special orders is $13,301), except ANSI 600 for which there was no sales that month. We did not change the average distributor prices because of the fact that the model does not account this unpredictable pricing behavior and works just on the assumed distributor prices in order to calculate a conservative estimate.

	ANSI 150	ANSI 300	ANSI 600	Special	Other	
	2897	6260	123195	12090	180	
	2800	1900	4850	26756	5123	
	1897	2655	6250	11276	300	
	7190	1195		8170	17954	
	2095			10790	4663	
	9615			11990	8947	
	7220				5072	
	3080				7981	
	1195				3093	
	1930				51	
	1895				81	
	1610				7756	
	3170				8276	
	7280				100	
	5000				120	
	1004				837	
	3510				610	
	5634				580	
	9360				620	
	1525				1000	
	3080				1640	
	2370				1405	
	2120				475	
	1140				378	
	1490					
	1690					
	1768					
	1490					
	1140					
	2210					
	1505					
To[illegible] Revenue	**99910**	**12010**	**134295**	**81072**	**77243**	**404529.7**
Total Selling	**68**	**6**	**27**	**9**		
Average Price	**1469**	**2001**	**4974**	**9008**		

Table 4.3a: Company's Revenue for the month of July

	ANSI 150	ANSI 300	ANSI 600	Special	Other	
	2982	6480	10200	16962	14364	
	5960	8710	13800	12990	19805	
	5605	8710	9010	20140	180	
	2270	9360	19200	86830	31.68	
	5160	4660	23800	23850	149.76	
	3530	2390	15200	24600	234.24	
	12448			13325	22.72	
	3786			7670	8364	
	2370				19314	
	4370				19639	
	3065				125	
	5110				600	
	3732.16				300	
	2810				3170	
	14160				1650	
	1210				500	
	975					
	1300					
	2890					
	709					
	3010					
	2500					
Total Revenue	**89952.16**	**40310**	**91210**	**206367**	**88449**	**516288.16**
Total Selling	**50**	**8**	**8**	**14**		
Average Price	**1799**	**5039**	**11401**	**14740.5**		

Table 4.3b: Company's Revenue for the month of August

	ANSI 150	ANSI 300	ANSI 600	Special	Other	
	4980	2885		17718	1200	
	6085	5230		61542	5526.56	
	3132.21	4130		45800	23673	
	2127.1	2880		7950	40960	
	3480	7055			1146.92	
	1770				6460	
	3708.78				1095	
	2945.21				286.73	
	2055				295	
	1154				120	
	4290				75	
	9000				109	
	1675					
	3890					
	5280					
	9579					
	1300					
	1600					
	3610					
Total Revenue	**71661.3**	**22180**	**0**	**133010**	**80947**	**307798.51**
Total Selling	**36**	**8**		**10**		
Average Price	**1990**	**2772.5**		**13301**		

Table 4.3c: Company's Revenue for the month of September

The high difference for the month August is mostly due to high real distributor price values. The negative values for the month September is because of lower real selling than the predicted. Looking at the real data it was observed that the amount of revenue generated by the "Other" is somewhat close to the revenue generated by ANSI 150. Therefore, the company could add this amount to the predicted revenue in order to have estimated total revenue.

In the long term, special orders with their long delivery times and relatively high value have to be considered separately. However, we do not have enough historical data to do this at the present time.

	July 2001			August 2001			September 2001		
	Predicted	Real (Only ANSI)	Diff	Predicted	Real (Only ANSI)	Diff	Predicted	Real (Only ANSI)	Diff
Total Revenue	$236,674	$246,215	4%	$329,825	$221,472	-49%	$246,885	$226,851	-8%
Total Selling	79	101	22%	110	66	-38%	63	44	-43%

Table 4.4: ***Final*** differences between the predicted and real values

Other possible reasons are

- average amounts that a distributor pay to company were used for the product types; e.g., average amount of $1500 was taken for the ANSI 150 type ;
- the average salary per employee was used;
- the average prices for raw material and machining were used.

4.4.1.9 Base Case

A base case run includes validation months but carried it out further in the future. It also gives a basis of comparison to do sensitivity analysis. Figures 4.15 and 4.16 (representing two base runs) show the base case for the company.

The base runs show the behavior of company for the next 48 months under the assumptions described above. Figures 4.15 shows the cash, total selling and revenue, and Figure 4.16 shows the backlog of orders for the company's three standard products.

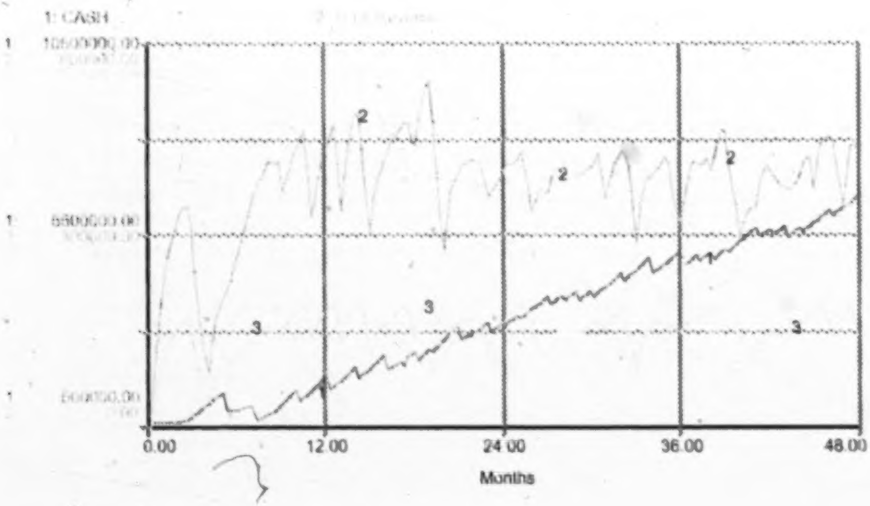


Figure 4.15: Financial parameters from base case

Curve 1 in Figure 4.15 represents the cash position of the company; curve 2 represents total revenue and curve 3 total selling for the company. Cash grows gradually with the time as it accumulates the revenue generated by the company. Total selling shows an unstable behavior because of the fact that good economy, reasonable price and good history factor increases the orders for the company and hence more sales, but with more sales machined inventory goes down and due to suppliers high delivery delay, the sales decreases. Total revenue follows the same pattern as total revenue is a function of total selling. Further detail of the behavior of the above shown curves is explained in the next section.

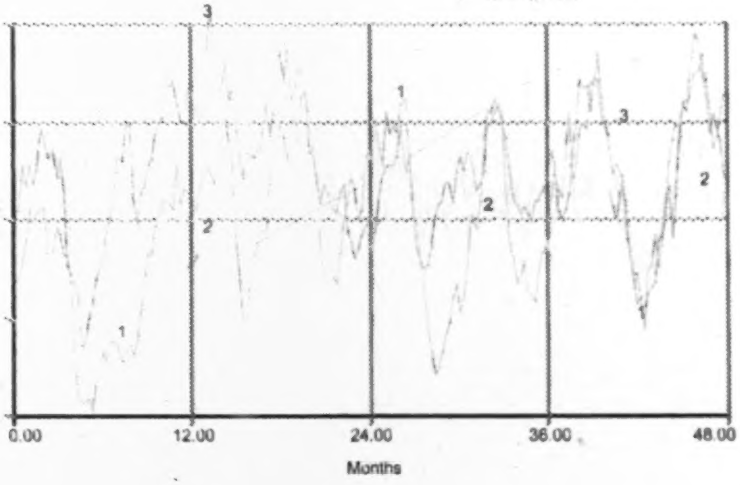


Figure 4.16: Ordering parameters from base case

Curve 1 in Figure 4.16 represents the backlog orders for ANSI 150; curve 2 and curve 3 represents backlog orders for ANSI 300 and ANSI 600 respectively. All three curves show an unstable behavior because of the reasons discussed above for total selling and detailed reasons why the specific behavior happens is discussed in the next section.

4.4.1.10 Feedback loops in the Model

The various sub-models of the company are interrelated with each other through "feedback loops". For example, the ordering rate generated in the ordering sub-model (Figure 4.5) influences the production sub-model (Figure 4.11). Figure 4.17 provides an example how different sub-models are interrelated with each other. In the Figure 4.17, increase of backlog of orders ("ORDERS 150" from production sub-model) will increase the finished parts ("FINISHED 150" in the production sub-model). This in turn reduces the inventory of machined material ("MC MATERIAL INVENTORY" in the production model) as well as selling (in the production sub-model). Less selling will increase the unmet orders for the company (in the ordering sub-model). Increasing unmet orders will decrease the history factor (in the ordering sector), that means distributors give fewer orders decreasing the ordering rate (in the ordering sub-model) for the company. This ordering rate in turn decrease the backlog orders for the company present in the production sub-model. Hence, the loop started with an increase of backlog of orders but ended with decreasing it, making a negative feedback loop in the system (also shown as Loop 1 in the Figure 4.19). Now take an example of a positive feedback loop as shown in the Figure 4.18, an increase in "Ordering Rate" increases the "Ordering" for a specific product, thus increases the "LAST MONTH ORDERS" for the company which in turn increases the "Perceived Orders" for the next month and hence the "Ordering Rate".

The performance of the whole system is influenced by the feedback loops presented in Figure 4.19, showing the relationship among the factors in the company's different sectors. The company's predicted performance is influenced by the seven

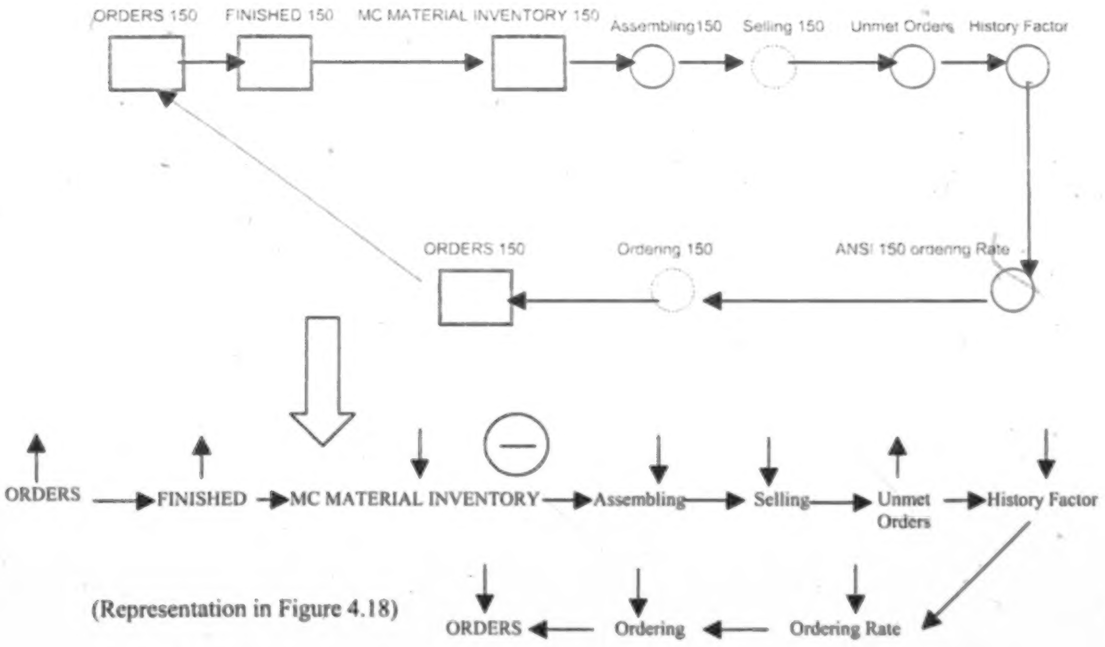

ORDERS 150
FINISHED 150
MC MATERIAL INVENTORY 150
Assembling150
Selling 150
Unmet Orders
History Factor
ORDERS 150
Ordering 150
ANSI 150 ordering Rate
ORDERS
FINISHED
MC MATERIAL INVENTORY
Assembling
Selling
Unmet Orders
History Factor
(Representation in Figure 4.18)
ORDERS
Ordering
Ordering Rate

Figure 4.17: Example of a negative feedback loop

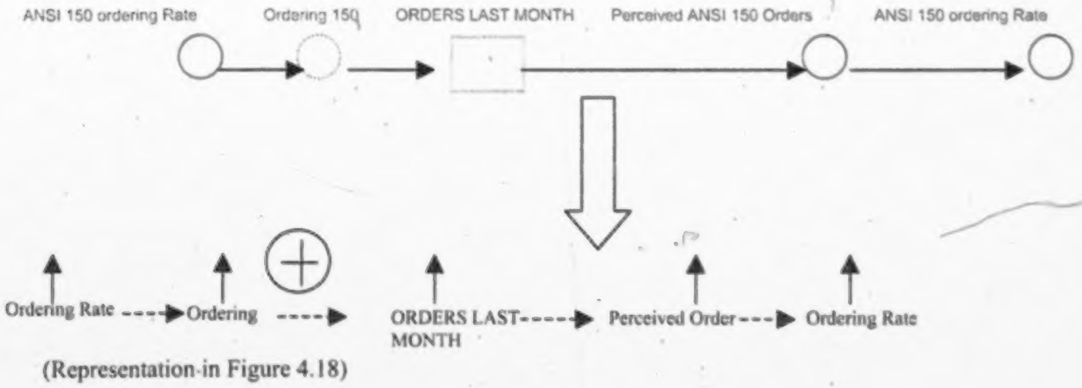

ANSI 150 ordering Rate
Ordering 150
ORDERS LAST MONTH
Perceived ANSI 150 Orders
ANSI 150 ordering Rate
Ordering Rate
Ordering
ORDERS LAST MONTH
Perceived Order
Ordering Rate
(Representation in Figure 4.18)

Figure 4.18: Example of a positive feedback loop

feedback loops present in the company's different sub-models. Four of them are positive, i.e., the loop starts and ends with the same increasing or decreasing trend. The other three are negative feedback loops, so that they do not end with the same trend with which they begin. The company's behavior for the next 48 months in the base runs is a result of all these feedback loops. The base runs start with assumption that company has $600,000 cash (from a short-term loan or private investment shown in the company's balance sheet) and that the supplier takes three months to deliver the machined material. The capacity of the major contractor does not change, and the days of receivables and payables are 45 days and 30 days, respectively. The positive feedback loops in the different models will act to increase the total sales, total orders, cash, and revenue for the company (Figure 4.15), but the negative feedback loops act as constraints on those increases. The backlog of orders shows a growing instability (Figure 4.16) because in a good economy, enough finished raw material will increase the company's orders, but as the stock of finished raw material decreases because of more selling, and the supplier takes a certain amount of time to supply finished raw material the selling decrease and in turn decrease the company's orders. If the negative feedback loops are stronger than the positive feedback loops, the performance of the company will be even unstable in the future.

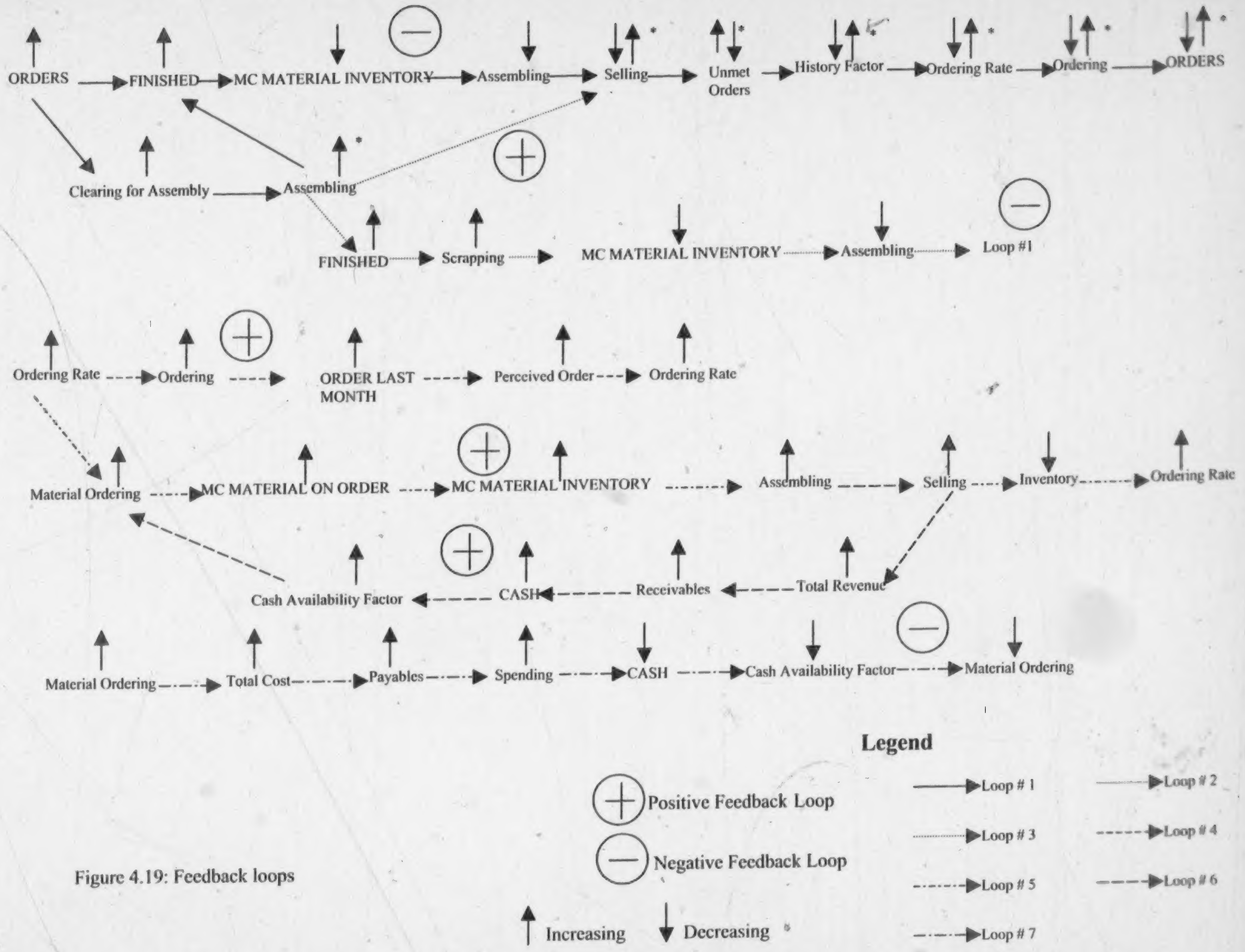

ORDERS
FINISHED
MC MATERIAL INVENTORY
Assembling
Selling
Unmet Orders
History Factor
Ordering Rate
Ordering
ORDERS
Clearing for Assembly
Assembling
FINISHED
Scrapping
MC MATERIAL INVENTORY
Assembling
Loop #1
Ordering Rate
Ordering
ORDER LAST MONTH
Perceived Order
Ordering Rate
Material Ordering
MC MATERIAL ON ORDER
MC MATERIAL INVENTORY
Assembling
Selling
Inventory
Ordering Rate
Cash Availability Factor
CASH
Receivables
Total Revenue
Material Ordering
Total Cost
Payables
Spending
CASH
Cash Availability Factor
Material Ordering
Legend
Positive Feedback Loop
Negative Feedback Loop
Increasing
Decreasing
Loop # 1
Loop # 2
Loop # 3
Loop # 4
Loop # 5
Loop # 6
Loop # 7

Figure 4.19: Feedback loops

4.4.2 Initial Performance measurement Framework

Every system consists of system results and the factors producing them. As we modeled the whole company as one system, it necessarily has some system results and factors influencing them. Therefore, our initial performance measurement framework consists of two types of measures (Figure 4.20), end-result indicators (Table 4.5) and the input factors influencing them (Table 4.6), the lower part of the Figure 4.20 show the interrelationship among different sub-models, like information from ordering sub-model goes to production sub-model. Information from production sub-model goes to financial sub-model as well as raw material cost sub-model and machining sub-model.

4.4.2.1 Selection of Performance Measures

Initially, performance measures were selected based on the discussion in Chapter 2. These measures had to be simple to measure and use the four aspects described by Neely (1997) discussed on page 51. These are described below:

4.4.2.2 End-Result Indicators

End-result indicators are the outcomes of the system generated by the model given the input factors. The end-result indicators show the outcomes of the company's model based on the system dynamics approach. These outcomes are the results of the interactions among the different parts of the model (or system). The end-result indicators include (also shown in Table 4.5):

1. Total revenue
2. Profit
3. Total selling

4. Cash in hand
5. Sales per employee
6. Total cost
7. Profit margin on sales
8. Material Cost ratio
9. Unmet orders

	End Result Indicator	**Unit**	**Definition**
1	Total Revenue (From Financial sub-model)	Cdn$	The total amount of money received from customers during the last month.
2	Profit (From Financial sub-model)	Cdn$	Total revenue – Total cost.
3	Total Selling (From Financial sub-model)	Number	Total Number of products sold last month.
4	Cash in Hand (From Cash flow sub-model)	Cdn$	The amount of money in hand.
5	Sales per Employee	Ratio	Total Revenue/ No. of employees.
6	Production Cost (From Financial sub-model)	Cdn$	Total cost of producing the orders in terms of labor cost, machining cost, but not overhead.
7	Profit Margin on sales	Ratio	Profit/Revenue
8	Material Cost ratio	%	Purchased material cost / revenue
9	Unmet Orders (From Ordering sub-model)	Number	Total number of orders that company was unable to deliver

Table 4.5: End-result indicators

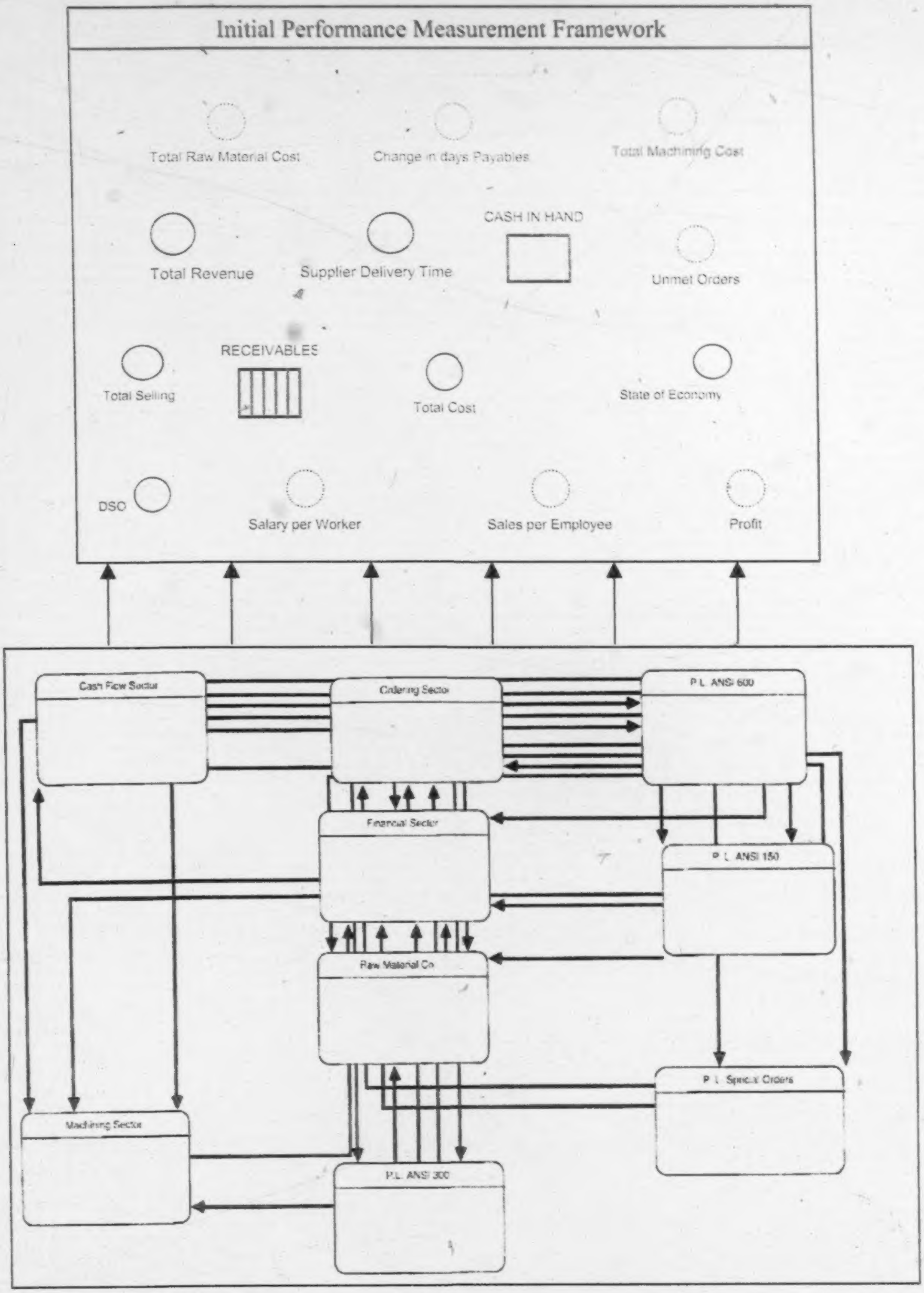

Initial Performance Measurement Framework
Total Raw Material Cost
Change in days Payables
Total Machining Cost
Total Revenue
Supplier Delivery Time
CASH IN HAND
Unmet Orders
RECEIVABLES
Total Selling
Total Cost
State of Economy
DSO
Salary per Worker
Sales per Employee
Profit
Cash Flow Sector
Ordering Sector
P.L. ANSI 600
Financial Sector
P.L. ANSI 150
Raw Material Co
P.L. Special Orders
Machining Sector
P.L. ANSI 300

Figure 4.20: Initial performance measurement framework generated from the company's model

End-results indicators are generated by the model given the input factors. For example, total selling is an end-result of various activities such as the product's delivery time, quality, and manufacturing time.

The ultimate goal for any company is linked with its revenue, profitability, and the amount of products sold, therefore, the end-result indicators can be considered as the actual results achieved.

4.4.2.3 Input factors influencing the end result indicators

The model generates outcomes (end-result indicators) under the influence of the input factors, which carry the information required by the model to give the end results. These input factors should also be measured constantly in order to ensure sustainable end results.

As was discussed in the previous chapter, our performance measurement framework was developed from the literature, which includes both end-result indicators and the input factors influencing them (see Table 4.6).

	Input Factors	Unit	Definition
1	Material Cost (From Raw material sub-model)	Cdn$	The total amount of money paid to suppliers for the material.
2	Receivables (From Cash flow sub-model)	Cdn$	The current amount of bills to be paid by the customers.
3	Days of Receivables (From Cash flow sub-model)	Days	Number of days required by the customers to pay their bills.
4	Days of Payables (From Cash flow sub-model)	Days	Number of days required by the company to pay its suppliers' bills.
5	Delivery Time (From Production sub-model)	Days	Number of days required for delivering the customers' orders.
6	Supplier Delivery Time (From production sub-model)	Days	Number of days required by the suppliers to deliver the material.
7	Major Supplier Capacity (From production sub-model)	Number	Total number of products that a major supplier can deliver within the same delivery time.
8	Scrap Rate (From production sub-model)	%	Percentage of finished products to be scrapped.
9	Salary per employee (From Financial sub-model)	Cdn$	Total cost of salaries and benefits.
10	Price of the product (From Financial sub-model)	Cdn$	Selling price of the product.
11	State of the economy (From Ordering sub-model)	Price of oil	State of the economy of the sector critical to the company. For the selected company, the oil sector is the major customer.

Table 4.6: Input factors

4.5 Dynamics of the Model

System performance was investigated by studying the performance of end-result indicators in terms of good or bad performance. If the current performance level is less than the previous than the overall performance of the company is bad. The discrepancy resulted in developing new strategies to improve the performance level in recommending specific actions to be taken by the company (as shown in Figure 4.1). Improving or changing only one input factor did not result in improving the overall performance of the company and did not significantly change the current status of the system. Therefore, to achieve the desired results or to reduce the discrepancy between the system's current and desired results, various input factors had to be changed. Changing various inputs to achieve the desired results can be termed a "strategy" for improving the overall system. Sensitivity analysis can test the strategies. The behavior of the system was observed first by varying only one input factor with different values. Doing so showed us the effect of this input factor on specific end-result indicators. After observing all the input factors, we devised strategies including different input factors, and then varied the values of each input factor and observed the behavior of the system.

The next chapter will use the initial performance measurement developed in this chapter and the effect of various input factors will be analyzed on the end-result indicators through sensitivity analysis, in order to develop company's final performance measurement framework and devise strategies.

CHAPTER 5

SENSITIVITY ANALYSIS AND THE NEW PERFORMANCE MEASUREMENT FRAMEWORK

5.1 Introduction

This chapter discusses the critical end-result indicators and critical input factors. These are the performance measures that constituted the company's final performance measurement framework. To identify the critical end-result indicators and input factors, an experimental matrix was developed, which showed the results of varying different input factor values on end-result indicators. The final performance measurement framework helps employees of the company to look after certain areas of performance. This chapter also provides an example of devising future strategies for the company based on the performance measures selected for it.

5.2 Experimental Matrix

Base runs show the predicted future performance based on the past performance of the system or company in the dynamic model of the performance measurement framework. This current state is compared with the desired goal (a good performance in terms of revenue, cash, and sales etc.). The discrepancy will result in developing strategies to achieve the desired goals. Strategies can be tested by sensitivity analysis, showing the results of different strategies.

As was described in the previous chapter, our performance measures are of two types: end-result indicators and the input factors influencing them. Sensitivity analysis will help us to determine the effect of the input factors on the end results. Regarding the sensitivity analysis due the issues in the validation of model as discussed before. There may be a tolerance for error assigned to each of the sensitivity runs due to the uncertainty in the data. However this should not change the relative positions of the runs' results, although it may change the absolute values of the parameters.

Table 5.1 shows the end-result indicators and Table 5.2 shows the input factors, which can be changed to determine their effects on the end results i.e. an experimental matrix (Table 5.3). These are discussed in the next sections. Sustainable growth in the future is the company's desired goal.

5.2.1 Critical End-Result Indicators

Critical end-result indicators are the best indicators of the performance of the whole system. From the feedback figure (Figure 4.19) presented in Chapter Four, total sales, total revenue, and cash are the end-result indicators present in the feedback loops. A good performance of these measures makes the positive feedback loops stronger for the whole system and in general improves the performance. For example, higher sales will result in more orders for the company, and higher revenue will result in more cash, if the customers pay on time. Other end-result indicators (as shown in Table 5.1) are the ratios of the end-result indicators, for example, the sales per employee is the ratio of the total revenue and the total number of employees. Higher revenue will result in a higher sales-per-employee ratio. The material-cost ratio is the ratio of the total raw material cost and the total revenue. Therefore, the growth of the company can be observed in terms of its total revenue, total orders, total selling and the cash they generate. These are the critical end-result indicators that a company should measure in order to ensure its future growth. Table 5.1 shows the total number of end-result indicators present in the model. The effect of the input factors can be determined by the model on the company's total revenue, total selling, and cash flow as these are the critical end-result indicators for the company to measure.

For small and medium-sized enterprises, Keegans *et al.*, 1989 suggested using few and simple performance measures. These end-result indicators occur too late to allow a company to take any corrective actions, but are necessary to measure the company's growth. A company should not concentrate solely on the end-result indicators, which are mostly traditional performance measures, but should measure the necessary ones as was discussed above. The most important performance measures for the company are those affecting the critical end-result indicators. Those can be observed well before bad end results occur so corrective actions can be taken because they are the main contributors to the company's growth.

	End Result Indicator
1	Revenue
2	Total Selling
3	Cash in Hand
4	Profit
5	Sales per Employee
6	Profit Margin on Sales
7	Material Cost Ratio
8	Unmet Orders
9	Total Cost

Table 5.1: End-result indicators

5.2.2 Critical Input Factors

As was discussed above, input factors are real time performance measures for the company, or the real contributors to the company's growth as they generate the company's end-results (in terms of sales, revenue and cash). Therefore, the company must measure the input factors regularly because if any necessary corrective actions are not taken in time, these factors will generate bad end-results. Like the critical end-result indicators present in the feedback loops, the critical input factors are those factors that could strengthen the negative feedback loops in the company's model. In other words, the critical input factors can cause the system to generate bad critical end results. Table 5.3 shows the input factors and their influence on the critical end-result indicators.

5.2.2.1 Example of Sensitivity Analysis

Effect of Economy factor on End result indicators: -

The effect of the state of the economy, i.e., price of oil, was observed on the critical end-result indicators. The price of oil varied (i.e. range in the Table 5.3) from $15-$35 per barrel for the four simulation runs for each critical end-result indicator.

Run #	Price of oil ($/bbl)
Run #1	35
Run #2	28.3
Run #3	21.7
Run #4	15

Table 5.2: Values for price of oil

Figure 5.1 shows the effect of oil prices on the company's total sales. Run 1 showed the simulation with an oil price value of $35/bbl, and runs 2, 3 and 4 showed simulations for the prices of $28.3, $21.7, and $15/bbl, respectively. The simulations reveals that the company gets more orders if the price of oil is $21.7/bbl, as it is in run 3. A too high oil price (run 1) and a low oil price (run 4) result in a low number of orders for the company.

The three Figures 5.1-5.3 shows that the company generates more sales, revenue, and cash if the oil price is $21.7 per barrel. Run 1($35/bbl) and run 4 ($15/bbl) in all figures showed a bad performance of the end-result indicators, indicating the effect of a very high and low price of oil, respectively.

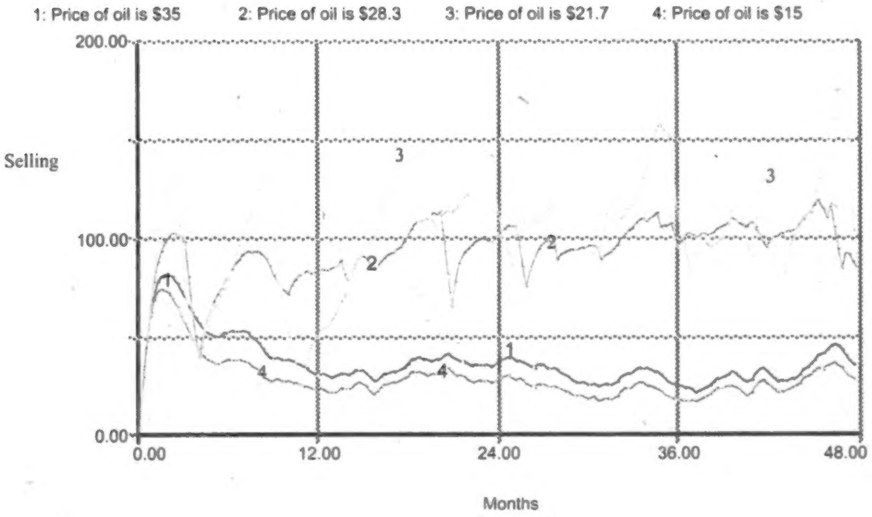


Figure 5.1: Effect of state of economy on total selling

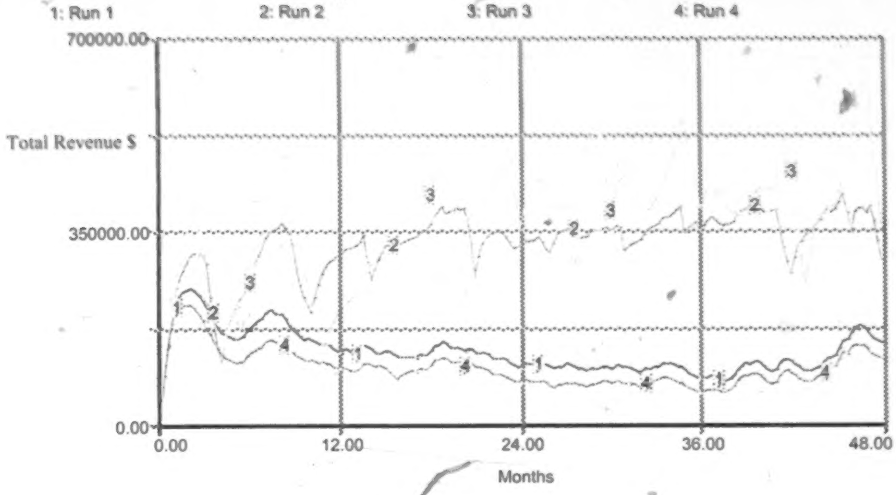


Figure 5.2: Effect of state of economy on total revenue

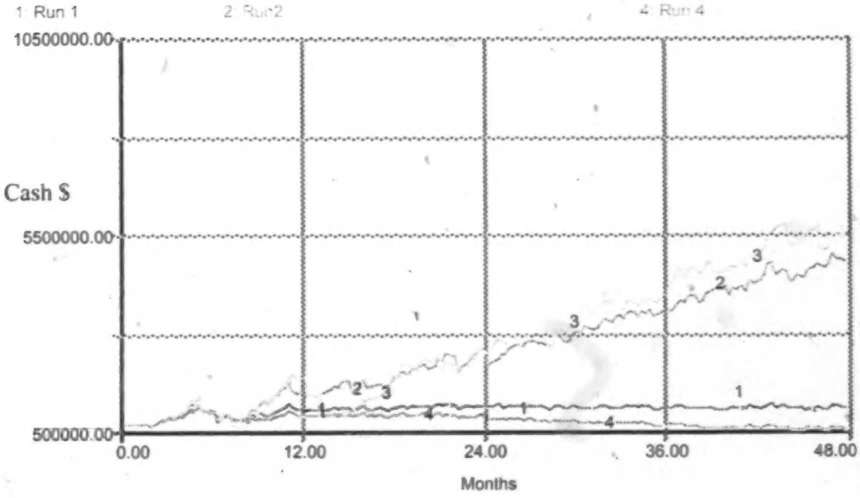


Figure 5.3: Effect of state of economy on cash

Table 5.3 summarizes the effects of various input factors on the critical end-result indicators and all input varied tables and respective figures are provided in the Appendix D. Based on the discussion of Table 5.3 shown below, we conclude that the following are the critical input factors to measure:

- state of the economy;
- day's receivables;
- supplier delivery time;
- major contractor supply capacity;
- scrap rate; and
- starting cash.

The state of the economy is defined in terms of the price of oil, and a price between the range of $20- $30 per barrel results in higher orders for the company. To fulfill this high demand, the company needs contractors with a large capacity to supply finished materials. As well, the company has to keep its scrap rate to a minimum value because high scrap rate will reduce the inventory of the machined raw material, reduce the assembling rate, and, hence, also reduce the company's sales. The days of receivables is also very crucial for the growth of small businesses, for in order to meet a higher demand for orders, a company needs more cash to pay its suppliers, by having less days of receivables helps a company to generate cash quickly.

All these factors, if performing poorly, would result in a company's overall poor performance in achieving the desired goals (sustainable growth in the future) because these factors make the negative feedback loops stronger than the positive ones.

Table 5.3: Input factors and their influence on end-result indicators

No.	Indicator	Range	Actual value as in a base run	Result
1	Days of Receivables or Days of Sales Outstanding (DSO)	30-90 Days	45 Days	Significant effect on cash. Cash increases if days of receivables are low. Effects total sales also, 30 to 45 days of receivables are good. 90 days results in less sales. Same with the revenue as it is a function of sales. Sensitive to the overall growth of the company.
2	Days of Payables	30-90 Days	30 Days	Significant effect on cash. Higher number of days of payables increases the cash position of the company. Total sales is also more for the company. But the company needs to decrease the supplier delivery delay in order to have a stable growth in total sales. Total revenue is more since revenue is a function of sales. Sensitive to the over-all growth of the company if payables are paid late. But this is not a desirable action because it might be a cause of losing a good supplier.
3	Supplier Delivery Time	30-120 Days	90 Days	Significant effect on cash, as with the time, the orders of the company increase, so it is desirable to decrease the supplier delivery time or increase the raw material orders. Longer delivery time of supplier will result in less selling. Less selling will decrease the number of orders for the next month. Sensitive to the overall growth of the company.
4	Major Supplier Capacity for ANSI 600	0-120 Number	60	Higher major supplier capacity is needed, as in the future, orders are increasing because of good economic conditions, so to generate more revenue, more sales and more cash, higher major supplier capacity is required. The end results indicators show even better results if the major supplier increases its capacity with a decrease in delivery time. Sensitive to the overall growth of the company.
5	Major Supplier Capacity for ANSI 300	0-60	30	Same as above
6	Major Supplier Capacity for ANSI 150	0-200	100	Same as above

7	Scrap Rate	0.5- 5%	1%	Cash increases with lower scrap rate. Having a lower scrap rate increases sales, and as a result, revenue is also higher. Sensitive to the growth of the company.
8	Salary per Employee	$2000-$3000	$3000	Although decreasing the salaries has a positive effect on the cash position of the company, doing so is not suggested because it might foster dissatisfaction in the employees and can decrease the productivity.
9	Change of Price in ANSI 600	$5850-$7150	$6500	Increasing the price of the product does not improve the cash position of the company, as the market is very competitive. Increasing the price will result in fewer orders and hence less sales and less revenue. Experiments show that company's current price generates the best cash flow.
10	Change of Price in ANSI 300	$2250-$2750	$2500	Same as above
11	Change of Price in ANSI 150	$1350-$1650	$1500	Same as above
12	State of Economy	$15-$35/bbl	$25.6/bbl	Oil price between the range of $20-$30 per barrel results in higher cash in hand, more revenue and more sales (See Figure 5.1-5.3). Other sensitivity analyses are shown in Appendix D). Very sensitive to the growth of the company, as it is the factor that will generate more orders.
13	Starting Cash	$0M-$1M	$0.6M	Starting cash in hand affects the ordering rate for the company in the future. Enough cash in hand ensures the company's position to sustain a high demand for orders and get more sales. Sensitive to the growth of the company.
14	Raw Material Cost	15-25%	20% of the product price	Cash decreases by increasing the cost of raw material and increases by decreasing the cost of raw material. Sensitive to the growth of the company.
15	Machining Cost	30-40%	35% of the product price	Cash decreases by increasing the cost of machining and increases by decreasing the cost of machining. Sensitive to the growth of the company.

- Continue Table 5.3: Input factors and their influence on end-result indicators

5.3 New Performance measurement Framework

Both critical end-result indicators and critical input factors can be used to build the company's new performance measurement framework. These are the performance measures which the company should measure in real time in order to ensure its future growth.

The framework includes both simple cost and non-cost performance measures that are very simple in nature, and that is good for small business to start. They need to measure only those factors that directly affect the product cost and factors that affect sales, like delivery delay, lead –time, and generating cash for the company or the days of sales outstanding. One of the most important factors is to measure how external factors like the state of the economy affect the company. Figure 5.4 shows the company's new performance measurement framework. The framework includes the above-mentioned performance measures present in the various sub-models of the company's overall model.

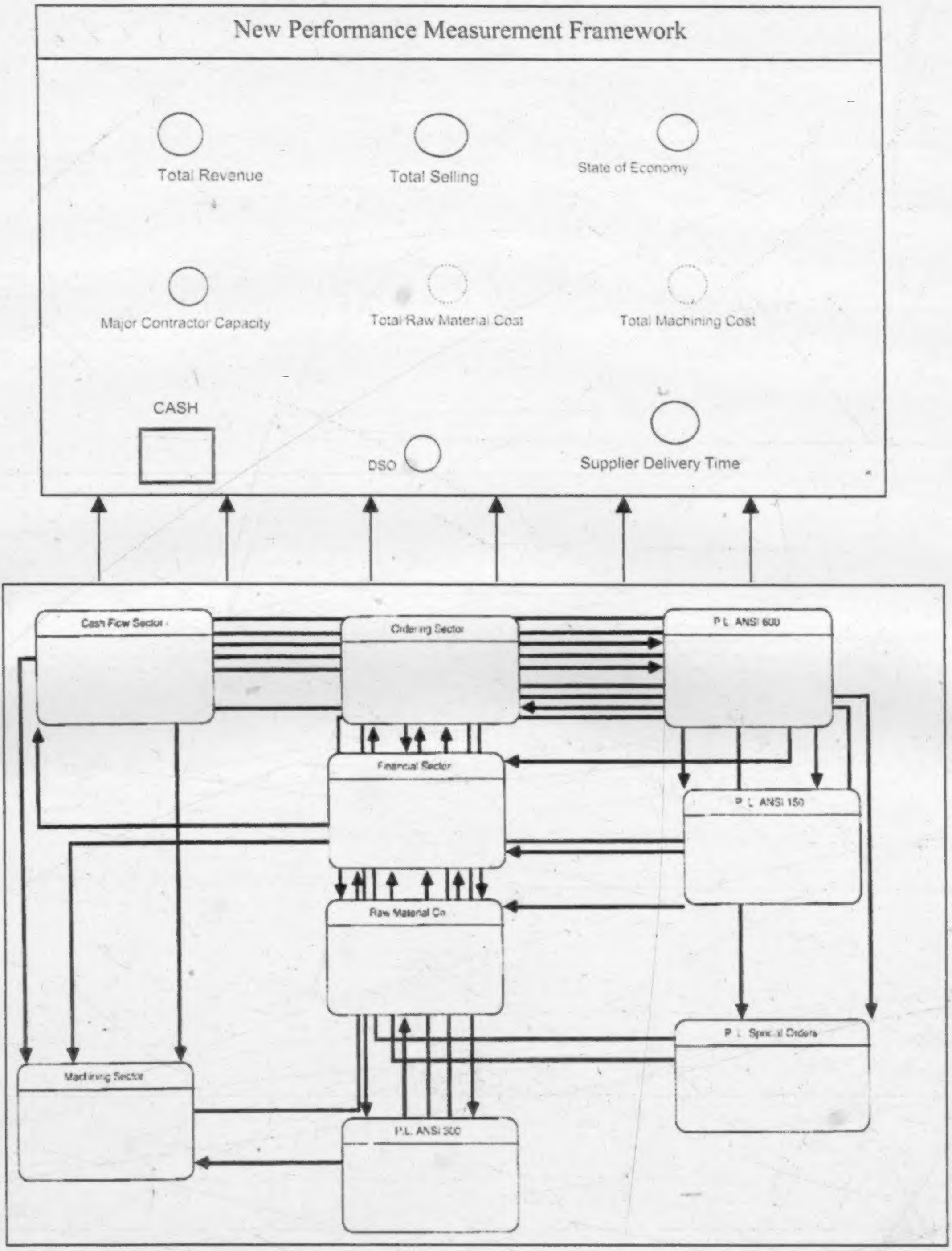

New Performance Measurement Framework
Total Revenue
Total Selling
State of Economy
Major Contractor Capacity
Total Raw Material Cost
Total Machining Cost
CASH
DSO
Supplier Delivery Time
Cash Flow Sector
Ordering Sector
P.L. ANSI 600
Financial Sector
P.L. ANSI 150
Raw Material Co
P.L. Special Orders
Machining Sector
P.L. ANSI 300

Figure 5.4: New performance measurement framework

5.4 Strategies for the future

As was discussed earlier the overall framework can be used to investigate possible strategies for the future. The company's behavior can be observed by the base runs discussed in Chapter Four. According to base run 1, the company will have a cash reserve of around $5.5 Million in four years and with an average maximum of 150 products sold monthly. As shown by the sensitivity analysis, for the company to grow further, it has to reduce the supplier delivery delay (see Table 5.3). One of the possible strategies for the company is to increase or decrease the prices of raw material and machining and in return, ask for a lower or longer delivery delay from the major contractor. Table 5.4 shows the values of the inputs for this strategy.

- Run 1 corresponds to the first strategy, i.e., decreasing the raw material cost and machining cost by 5% and 2 %, respectively, and asking for a delivery time of 4 months.
- Run 2 corresponds to the second strategy, i.e., decreasing the raw material cost and machining cost by 3% and 1 %, respectively, and asking for a delivery time of 3 months.
- Run 3 corresponds to the third strategy, i.e., increasing the raw material cost and machining cost by 2% and 1 %, respectively, and asking for a delivery time of 2 months.
- Run 4 corresponds to the fourth strategy, i.e., increasing the raw material cost and machining cost by 5% and 2 %, respectively, and asking for a delivery time of 1 month.

Figures 5.5 to 5.7 show the effect of each strategy (runs 1 to 4) on the company's total selling, total revenue, and cash. Results show that increasing the raw material percentage by 2 percent and the machining percentage by 1 percent, with a required delivery delay of 2 months (Run 3), would be a good option. The best option for the company is to increase the raw and machining material percentages by 5 and 2 percent, respectively, and ask for a delivery delay of one month (Run 4). The other two strategies (Run 1&2), which include decreasing the raw material and machining costs and a longer delivery time for the contractors, do not yield good results.

Run #	Change in cost of raw material (20% of the product price in the base run)	Change in cost of machining (35% of the product price in the base run)	Delivery time for supplier (3 months in the base run)
Run #1	15 %	33%	4
Run #2	17%	34%	3
Run #3	22%	36%	2
Run #4	25%	37%	1

Table 5.4: Values of inputs for the strategy

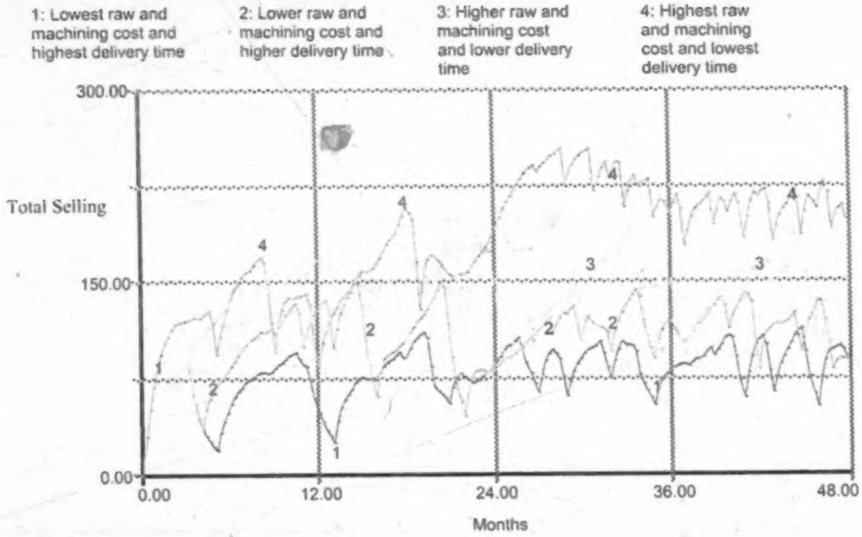


Figure 5.5: Effect of strategy on total selling

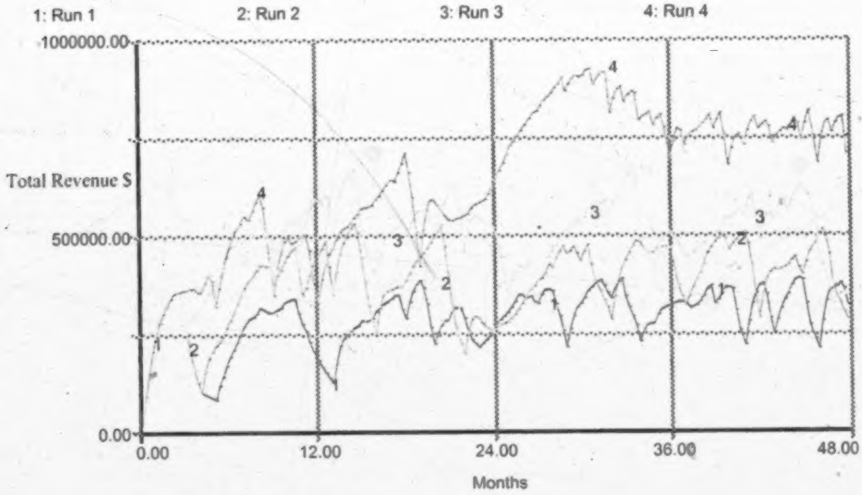


Figure 5.6: Effect of strategy on total revenue

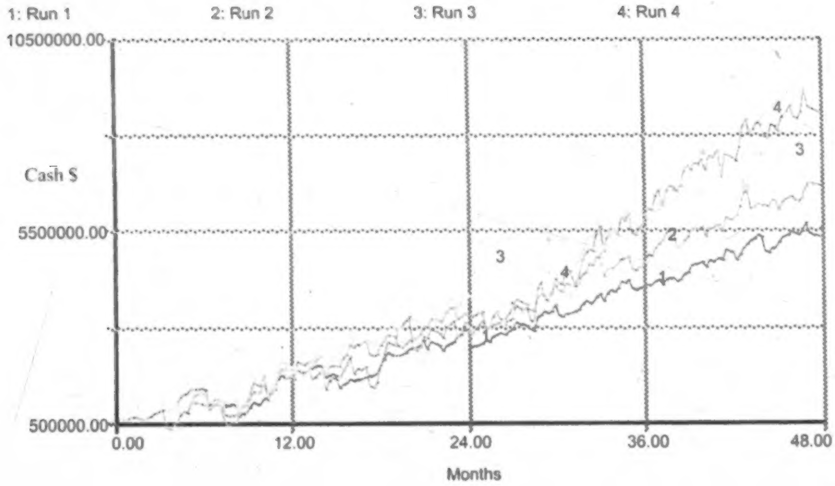


Figure 5.7: Effect of strategy on cash

Therefore, according to above strategy the company can pay more to its subcontractor and raw material suppliers asking for a lower delivery time and still achieving good performance of the end-result indicators.

The above-mentioned strategy is just one example of devising a strategy for the company; senior managers can experiment with different combinations also. By this company can go for a strategy, which is easy to implement in real and achieves good results for the company. In general SMEs can benefit from this as it can save their resources (in terms of money and labor) by implementing an economical strategy and give SMEs a way to plan strategically.

CHAPTER 6

CONCLUSIONS AND FUTURE RESEARCH

6.1 Summary, Conclusions, and Recommendations

- A dynamic framework for performance measurement has the potential to help a company to make strategies for the future, as a model incorporates external factors affecting the company's internal processes. With the help of a dynamic model, managers may be able to predict the company's future performance under the current operational values. A discrepancy between the predicted and desired goals will be noticed, and with the help of sensitivity analysis, those performance areas that can reduce the gap between the predicted and desired goals will be identified. Using a dynamic model also indicates what specific action a company should take. For example, in order to reduce the days of receivables to improve the company's cash position, the accounting department needs to be more efficient in getting the customers to pay on time. The model provides a method for making strategies and also provides a framework to manage their performance. In addition, or rather than continuously running the model various performance areas can be monitored and used to better manage the performance.
- A new performance measurement framework was suggested in this thesis. As the literature suggests the new performance measurement framework for the company has a few simple measures because of the limitations of small businesses. The framework includes cost and non-cost performance measures. Small businesses

should start with a few simple performance measures. The new performance measurement framework includes critical end-result indicators, which measures the company's growth and are the company's total revenue, total sales, total orders and cash position. All these can be categorized as traditional performance measures, but small business should measure them, for they are the critical ones. Small business should not measure all the traditional performance measures and cost ratios: small businesses lack the resources to do so and traditional performance measures are not directly related to the manufacturing strategy and are not meaningful to control the production and distribution processes. The other critical measures in the framework are those input factors affecting the company's performance or, in other words, affecting end-result indicators. These measures are the most important performance measures for the company.

- Feedback loops show the interrelationships among a company's different performance measures. As all the literature suggests by regarding performance measurement, performance measures should relate to each other. Therefore, the dynamic model for performance measurement also provides a means to understand the company's behavior by revealing the interrelationships among the company's different parts or different performance areas.

6.2 Future Research

- The model presented in the thesis indicates the company's critical performance areas but does not indicate how to achieve the desired performance levels in those areas. While this set of measures is useful as a starting point for a performance measurement system, it is by no means complete. Further research investigating different techniques for converting this initial set of performance measures into a functioning performance measurement system would be a valuable addition to the work presented here.

- The model incorporates only the price of oil as an external factor affecting the company and was studied. Further quantification of the many relationships affecting the company would need to be examined in order to design a more realistic model for it. Also there is a need to separate out special orders, others and the add-ons to regular ones, as they behave differently and are a large contributor to revenue.
- A similar type of manufacturing company could be modeled to validate the new performance measurement framework for small businesses.
- Different sectors of the model can be used in modeling other companies because of the general applicability of the different sectors. For example, the financial sector in the model is very typical of that of any kind of organization.

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Appendix A – The Questionnaire

Company Profile

Name of the Company: - ____________________

Address: - ____________________

City: - ____________ Province: - ____________

Postal Code: - ____________

Phone no.: - ( ) ___-___ Fax: - ( ) ___-___

Type of Company: - Manufacturing / Service

For how many years your company has been in business? ____________

What were the gross sales (Revenue) of the company last year? ____________

Number of current employees in the company

Full Time ________

Part Time ________

How is ownership is made up?

___ Sole proprietorship

___ Partnership

___ Incorporated

Principal's Name(s): - ____________

____

____

Name of Interviewee: - ____________

Operations

How does the company operate? ______________________________

____

____

____

____

____

Products and Ordering

Who are your major customers, what products do you supply them? __________

____

____

____

How do you categorize your products – as a service, as product lines or as product families? What are they and what percentage of the business does each represent? ______

____

____

____

How does the company get orders in every service they provide? __________

____

____

____

List all types of orders: - ______________________________

____

1. Are there any seasonal orders? If yes describe the months of getting that and the number of orders? ____________________

____

____

2. Is there any impact of economy in getting orders? Yes / No
    a. If yes: - what is the relationship? ____________________

____

3. Is delivery delay or delay in service affecting orders? Yes / No
    b. If yes what is the relationship? ____________________

____

4. Is cost (of product or service) affecting orders? Yes / No
    c. If yes what is the relationship? ____________________

____

____

5. What are the other factors affecting orders and how do they impact the orders?

____

____

____

Personnel

What is the total number of employees? ____________________

How many shop floor employees are at the plant not containing foreman or people who do mostly administrative work? ____________________

What is the average time to train an employee? ______________________________

What is your employee turnover rate in Production and in Administrative department?

____

____

____

Is there any effect of employee turn over on the production rate? __________________

____

____

____

What are the other factors affecting the personnel and how do they impact the personnel?

____

____

____

Manufacturing and Production

How does the company process the orders? ____________________________________

____

____

How do you calculate your production rate? ____________________________________

____

____

What is the range of lead-times from order to delivery? ________________________

What is the dollar/percentage of the following type of inventory?

Raw Materials? $____________ ____________%

In process Materials? $____________ ____________%

Finished Goods? $____________ ____________%

What is your scrap rate? ____

What is your rework rate? ____

How are the scrap and rework rates determined? ____________________

____

____

____

What is the cost of scrap as a percentage of total operating cost? ______________

What is the cost of rework as a percentage of total operating cost? ______________

How you calculate the productivity of the worker? ____________________

____

____

What is the ideal machine to worker ratio (or jobs/worker)?____________________

____

If using machines, what is your machine failure rate? ____________________

How long does it take to fix a machine (Maintainability)? ____________________

____

Monthly machine capacity? ____

What time is required for purchasing, transporting, installing and bring a new machine to the full production capacity? ____

What are the other factors affecting manufacturing and how do they impact the manufacturing? ______

______

______

______

Selling

How selling (service / products) is performed in your company? ______

______

______

______

______

What is the effect of delivery delay on selling? ______

______

______

______

______

______

What are the other factors affecting selling and how do they impact the selling? ______

______

______

______

Financial

How do you calculate your company revenue? ______________________________

____

____

How do you calculate your cost of production? ______________________________

____

____

What is your cost of selling the products and/or services? ____________________

____

____

What were your gross sales for the last fiscal year? ______________________________

What has been the trend of gross sales for the last five years? ________________

____

What was the profit margin last year? ______________________________

What is the return on sales for the last year? ______________________________

What has been the trend of your return on sales over the last five years? __________

____

What is the salary per employee? ______________________________

What is your overall overhead? ______________________________

What are the other factors influencing the financial standing of the company and how do they impact that? ______________________________

____

Marketing and Promotion

What techniques do you use to promote and sell your products and /or services? ______

____

____

What is your average promotion spending (in terms of per unit)? ______________

Is there any effect of promotion on getting orders? ______________________

____

____

____

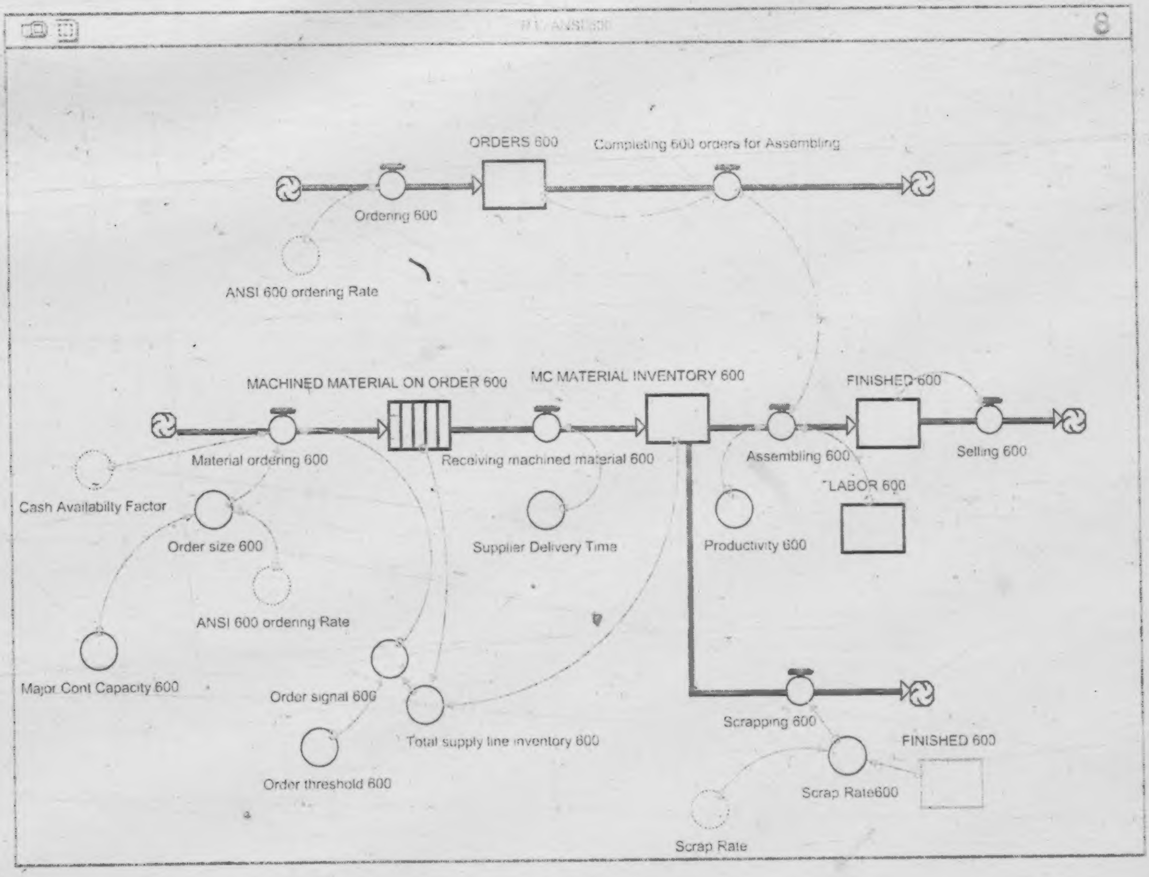
What are the other factors affecting marketing and promotion and how do they impact that? ______________________________

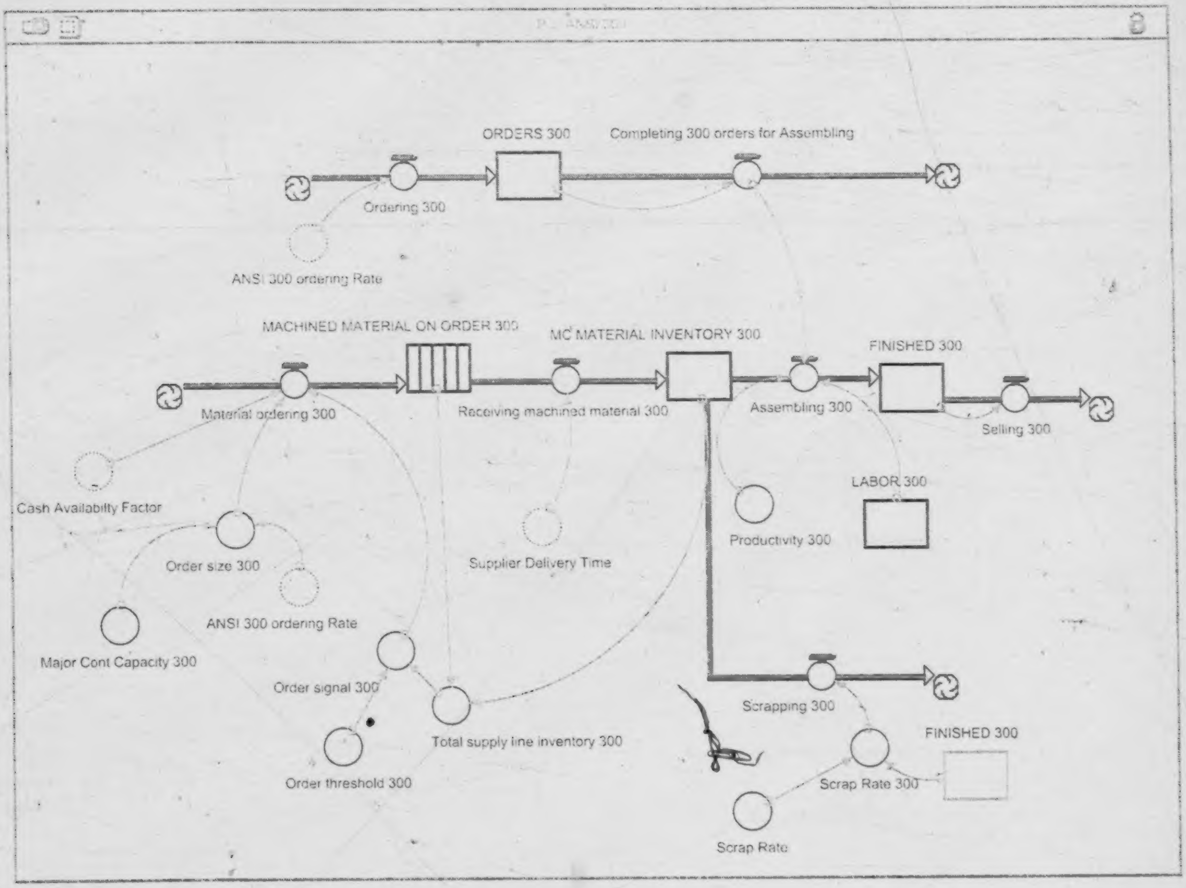
____

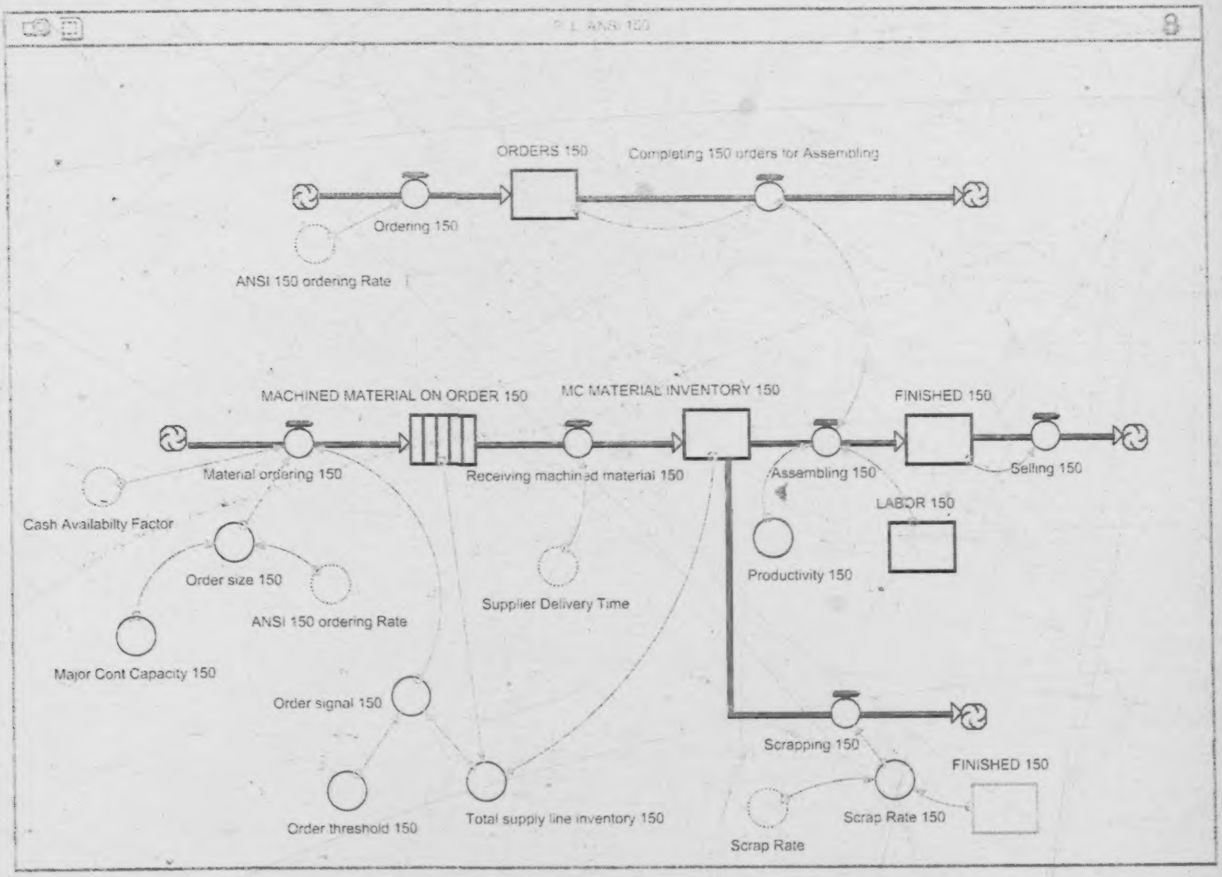
____

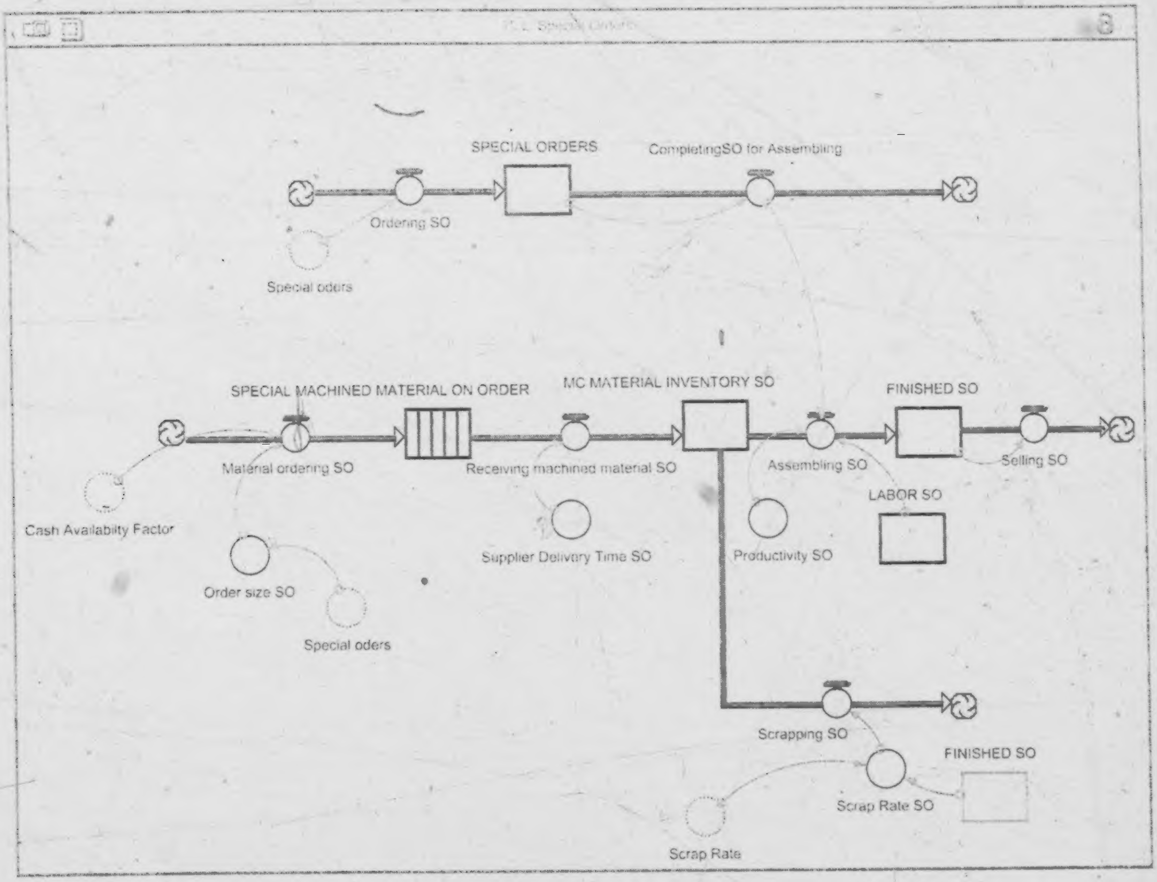
____

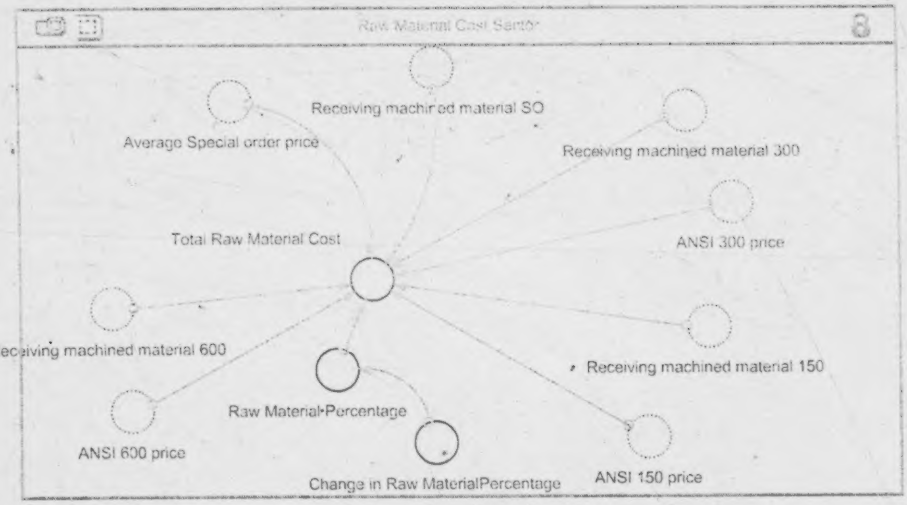
Appendix B: The model and the equations for the model

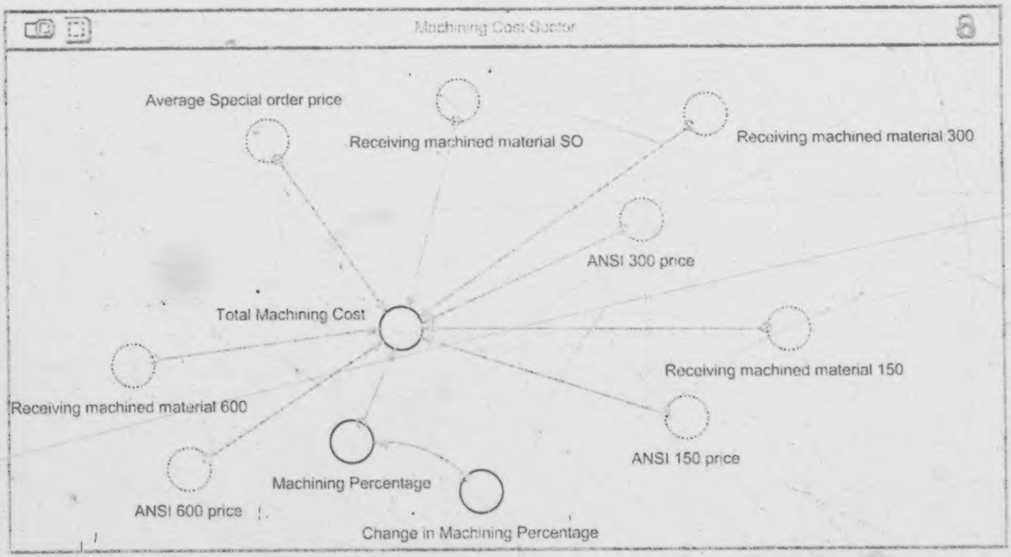

ORDERS 600
Completing 600 orders for Assembling
Ordering 600
ANSI 600 ordering Rate
MACHINED MATERIAL ON ORDER 600
MC MATERIAL INVENTORY 600
FINISHED 600
Material ordering 600
Receiving machined material 600
Assembling 600
Selling 600
Cash Availability Factor
LABOR 600
Order size 600
Supplier Delivery Time
Productivity 600
ANSI 600 ordering Rate
Major Cont Capacity 600
Order signal 600
Total supply line inventory 600
Scrapping 600
FINISHED 600
Order threshold 600
Scrap Rate600
Scrap Rate

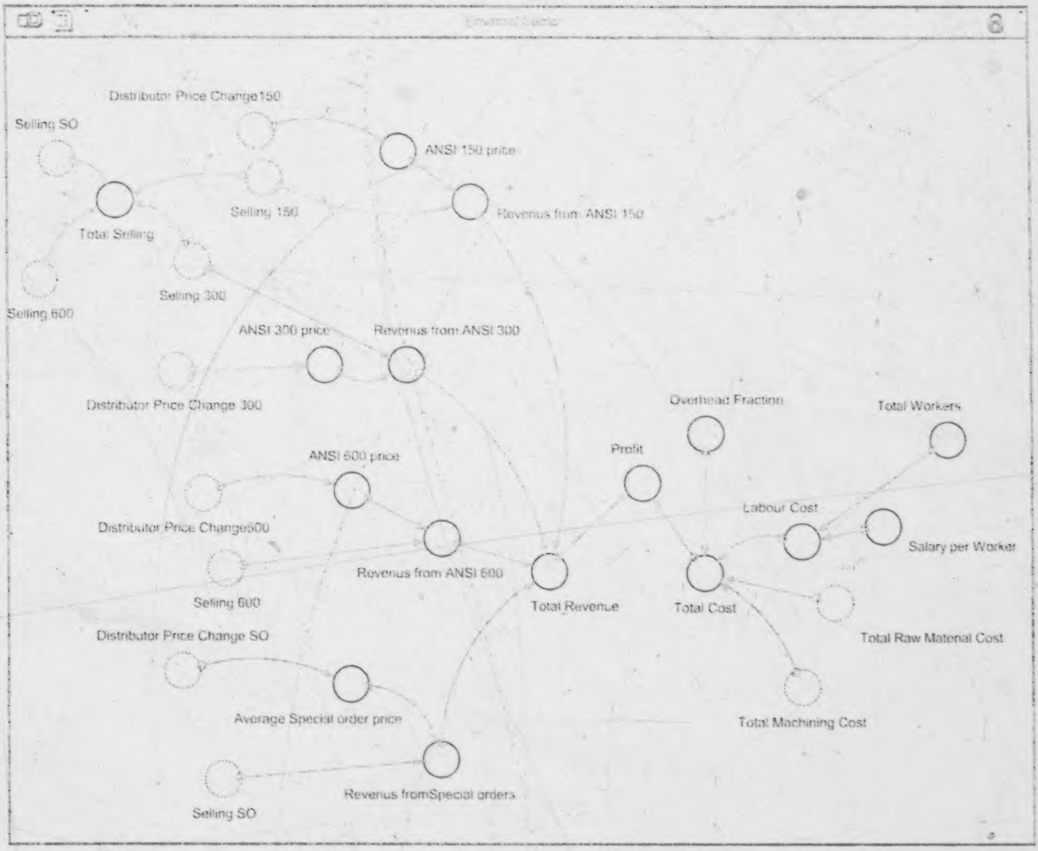

ORDERS 300
Completing 300 orders for Assembling
Ordering 300
ANSI 300 ordering Rate
MACHINED MATERIAL ON ORDER 300
MC MATERIAL INVENTORY 300
FINISHED 300
Material ordering 300
Receiving machined material 300
Assembling 300
Selling 300
Cash Availabilty Factor
LABOR 300
Productivity 300
Order size 300
Supplier Delivery Time
ANSI 300 ordering Rate
Major Cont Capacity 300
Order signal 300
Scrapping 300
Total supply line inventory 300
FINISHED 300
Order threshold 300
Scrap Rate 300
Scrap Rate

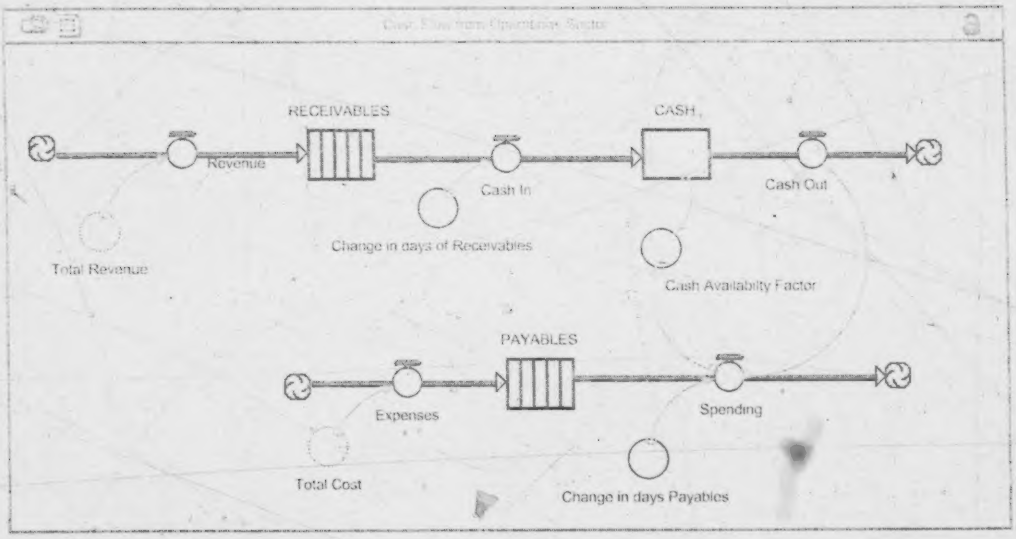

P L ANSI 150
ORDERS 150
Completing 150 orders for Assembling
Ordering 150
ANSI 150 ordering Rate
MACHINED MATERIAL ON ORDER 150
MC MATERIAL INVENTORY 150
FINISHED 150
Material ordering 150
Receiving machined material 150
Assembling 150
Selling 150
LABOR 150
Cash Availabilty Factor
Order size 150
ANSI 150 ordering Rate
Supplier Delivery Time
Productivity 150
Major Cont Capacity 150
Order signal 150
Scrapping 150
FINISHED 150
Order threshold 150
Total supply line inventory 150
Scrap Rate 150
Scrap Rate

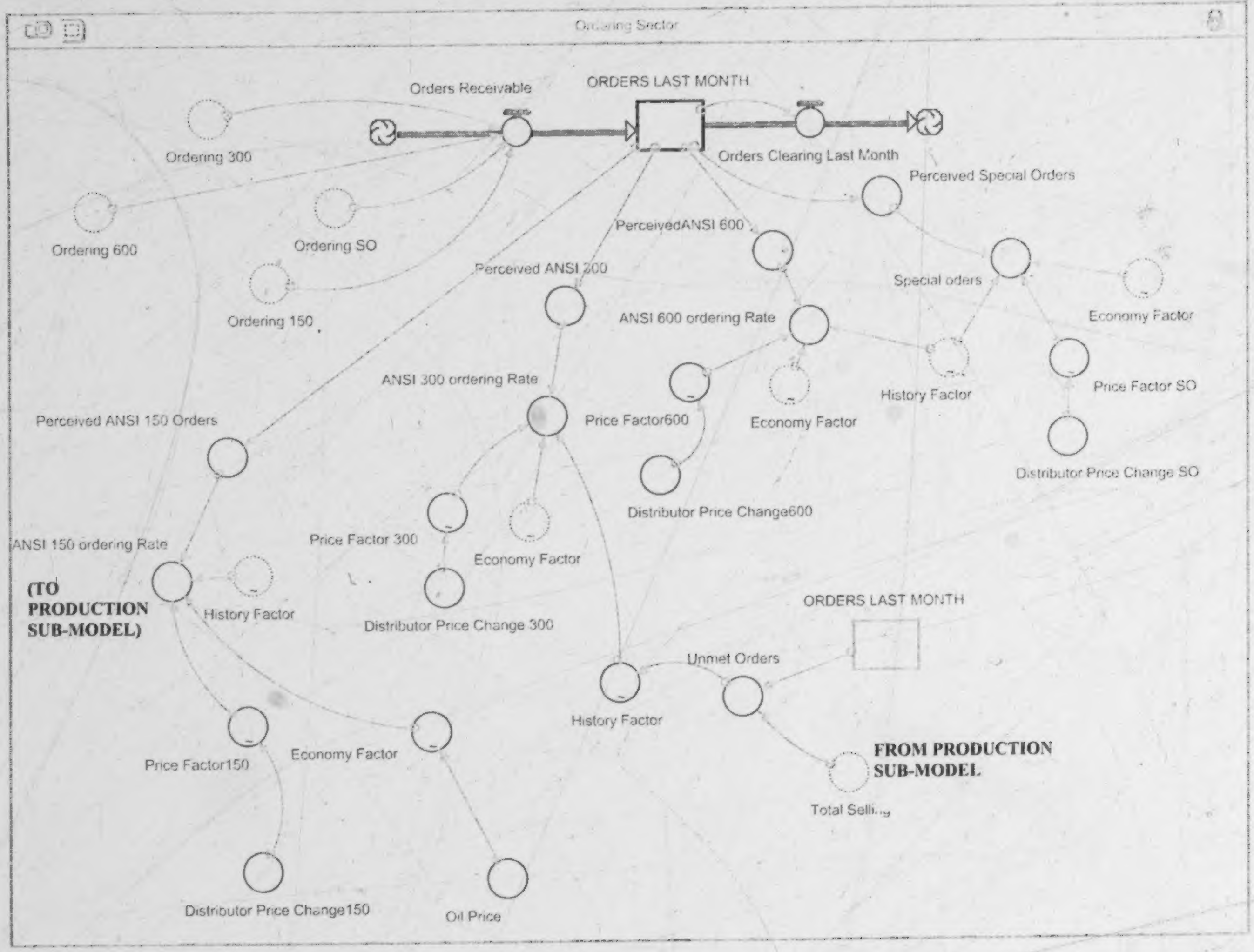

Special Orders
SPECIAL ORDERS
CompletingSO for Assembling
Ordering SO
Special oders
SPECIAL MACHINED MATERIAL ON ORDER
MC MATERIAL INVENTORY SO
FINISHED SO
Material ordering SO
Receiving machined material SO
Assembling SO
Selling SO
Cash Availabilty Factor
Supplier Delivery Time SO
Productivity SO
LABOR SO
Order size SO
Special oders
Scrapping SO
FINISHED SO
Scrap Rate SO
Scrap Rate


Raw Material Cost Sector
Receiving machined material SO
Average Special order price
Receiving machined material 300
ANSI 300 price
Total Raw Material Cost
Receiving machined material 600
Receiving machined material 150
Raw Material Percentage
ANSI 600 price
Change in Raw MaterialPercentage
ANSI 150 price


Machining Cost Sector
Average Special order price
Receiving machined material SO
Receiving machined material 300
ANSI 300 price
Total Machining Cost
Receiving machined material 150
Receiving machined material 600
ANSI 150 price
Machining Percentage
ANSI 600 price
Change in Machining Percentage


Distributor Price Change150
Selling SO
ANSI 150 price
Selling 150
Revenue from ANSI 150
Total Selling
Selling 300
Selling 600
ANSI 300 price
Revenue from ANSI 300
Distributor Price Change 300
Overhead Fraction
Total Workers
ANSI 600 price
Profit
Labour Cost
Salary per Worker
Distributor Price Change600
Revenue from ANSI 600
Selling 600
Total Revenue
Total Cost
Total Raw Material Cost
Distributor Price Change SO
Average Special order price
Total Machining Cost
Revenue fromSpecial orders
Selling SO


Cash Flow from Operations Sector
RECEIVABLES
CASH
Revenue
Cash In
Cash Out
Change in days of Receivables
Total Revenue
Cash Availabilty Factor
PAYABLES
Expenses
Spending
Total Cost
Change in days Payables


Ordering Sector
Orders Receivable
ORDERS LAST MONTH
Ordering 300
Orders Clearing Last Month
Perceived Special Orders
Ordering 600
Ordering SO
PerceivedANSI 600
Perceived ANSI 200
Special oders
Economy Factor
Ordering 150
ANSI 600 ordering Rate
History Factor
Price Factor SO
ANSI 300 ordering Rate
Perceived ANSI 150 Orders
Price Factor600
Economy Factor
Distributor Price Change SO
Distributor Price Change600
ANSI 150 ordering Rate
Price Factor 300
Economy Factor
(TO
PRODUCTION
SUB-MODEL)
History Factor
Distributor Price Change 300
ORDERS LAST MONTH
Unmet Orders
History Factor
FROM PRODUCTION
SUB-MODEL
Price Factor150
Economy Factor
Total Selli...
Distributor Price Change150
Oil Price

Equations:

Cash Flow from Operations Sector

CASH(t) = CASH(t - dt) + (Cash_In - Cash_Out) * dt

INIT CASH = 600000

DOCUMENT: Amount of cash available to company to pay their expenses.

INFLOWS:

Cash_In = CONVEYOR OUTFLOW

TRANSIT TIME = 2+NORMAL(Change_in_days_of_Receivables,.5,60)

DOCUMENT: Amount of money collected from the customers.

OUTFLOWS:

Cash_Out = Spending

DOCUMENT: Amount of cash out in order to meet the spending.

PAYABLES(t) = PAYABLES(t - dt) + (Expenses - Spending) * dt

INIT PAYABLES = 0

TRANSIT TIME = varies

INFLOW LIMIT = INF

CAPACITY = INF

DOCUMENT: Amount of money payable to employees and suppliers.

INFLOWS:

Expenses = Total_Cost

DOCUMENT: Monthly expenses of the company.

OUTFLOWS:

Spending = CONVEYOR OUTFLOW

TRANSIT TIME = 1+Change_in_days_Payables

DOCUMENT: Money spending by company every month.

RECEIVABLES(t) = RECEIVABLES(t - dt) + (Revenue - Cash_In) * dt

INIT RECEIVABLES = 0

TRANSIT TIME = varies

INFLOW LIMIT = INF

CAPACITY = INF

DOCUMENT: Amount of money that has to be collected from customers.

INFLOWS:

Revenue = Total_Revenue

DOCUMENT: Amount of revenue coming every month

OUTFLOWS:

Cash_In = CONVEYOR OUTFLOW

TRANSIT TIME = 2+NORMAL(Change_in_days_of_Receivables,.5,60)

DOCUMENT: Amount of money collected from the customers.

Change_in_days_of_Receivables = -.5

Change_in_days_Payables = 0

Cash_Availabilty_Factor = GRAPH(CASH/Spending)

(0.00, 0.00), (0.25, 0.00), (0.5, 0.00), (0.75, 0.00), (1.00, 1.00)

Financial Sector

ANSI_150_price = 1500+Distributor_Price_Change150

DOCUMENT: Price of product in dollars.

ANSI_300_price = 2500+Distributor_Price_Change_300

DOCUMENT: Price of product in dollars.

ANSI_600_price = 6500+Distributor_Price_Change600

DOCUMENT: Price of product in dollars.

Average_Special_order_price = 10000+Distributor_Price_Change_SO

DOCUMENT: Price of product in dollars.

Labour_Cost = Salary_per_Worker*Total_Workers

DOCUMENT: Labor cost per month (Dollars/Month)

Overhead_Fraction = 0.05

DOCUMENT: (N/A). No units. This is the fraction of the total cost allocated to overhead (management) costs.

Profit = Total_Revenue-Total_Cost

DOCUMENT: Profit generated per month. (Dollars/Month)

Revenus_fromSpecial_orders = Average_Special_order_price*Selling_SO

DOCUMENT: Revenue generated per month (Dollars/ Month).

Revenus_from_ANSI_150 = Selling_150*ANSI_150_price

DOCUMENT: Revenue generated per month (Dollars/ Month).

Revenus_from_ANSI_300 = Selling_300*ANSI_300_price

DOCUMENT: Revenue generated per month (Dollars/ Month).

Revenus_from_ANSI_600 = Selling_600*ANSI_600_price

DOCUMENT: Revenue generated per month (Dollars/ Month).

Salary_per_Worker = 3000

DOCUMENT: Average salary per month (Dollars/Month).

Total_Cost = (1+Overhead_Fraction)*(Labour_Cost+Total_Machining_Cost+Total_Raw_Material_Cost)

DOCUMENT: Total Cost per month for producing the products (Dollars/Month).

Total_Revenue = Revenus_fromSpecial_orders+Revenus_from_ANSI_150+Revenus_from_ANSI_300+Revenus_from_ANSI_600

DOCUMENT: Total revenue generated per month.(Dollars/Month).

Total_Selling = Selling_150+Selling_300+Selling_600+Selling_SO

Total_Workers = 14

DOCUMENT: Total number of employees.

Machining Cost Sector

Change_in_Machining_Percentage = 0

Machining_Percentage = .35+Change_in_Machining_Percentage

Total_Machining_Cost = ((Average_Special_order_price*receiving_machined_material_SO)+(Receiving_machined_material_150*ANSI_150_price)+(Receiving_machined_material_300*ANSI_300_price)+(Receiving_machined_material_600*ANSI_600_price))*Machining_Percentage

DOCUMENT: Total machining cost in dollars per month (Dollars/Month)

Ordering Sector

ORDERS_LAST_MONTH(t) = ORDERS_LAST_MONTH(t - dt) + (Orders_Receievable - Orders_Clearing_Last_Month) * dt

INIT ORDERS_LAST_MONTH = 120

DOCUMENT: Last month Number of Orders.

INFLOWS:

Orders_Receievable = Ordering_150+Ordering_300+Ordering_600+Ordering_SO

DOCUMENT: Total Orders receive per month.

OUTFLOWS:

Orders_Clearing_Last_Month = ORDERS_LAST_MONTH

DOCUMENT: Orders cleared last month.

ANSI_150_ordering_Rate =
Perceived_ANSI_150_Orders*Economy_Factor*Price_Factor150*History_Factor

DOCUMENT: Actual order rate per month.

ANSI_300_ordering_Rate =
Perceived_ANSI_300*Economy_Factor*Price_Factor_300*History_Factor

DOCUMENT: Actual order rate per month.

ANSI_600_ordering_Rate =
PerceivedANSI_600*Economy_Factor*Price_Factor600*History_Factor

DOCUMENT: Actual order rate per month.

Distributor_Price_Change150 = 0

DOCUMENT: Change in the price of product (Dollars).

Distributor_Price_Change600 = 0

Distributor_Price_Change_300 = 0

DOCUMENT: Change in the price of product (Dollars).

Distributor_Price_Change_SO = 0

DOCUMENT: Change in the price of product (Dollars).

Oil_Price = 25.6

DOCUMENT: Price of Oil.

PerceivedANSI_600 = .26*ORDERS_LAST_MONTH

DOCUMENT: Number of orders perceived from the total last month orders.

Perceived_ANSI_150_Orders = .6*ORDERS_LAST_MONTH

DOCUMENT: Number of orders perceived from the total last month orders.

Perceived_ANSI_300 = 0.06*ORDERS_LAST_MONTH

DOCUMENT: Number of orders perceived from the total last month orders.

Perceived_Special_Orders = .08*ORDERS_LAST_MONTH

DOCUMENT: Number of orders perceived from the total last month orders.

Special_oders =
Perceived_Special_Orders*Economy_Factor*Price_Factor_SO*History_Factor

DOCUMENT: Actual order rate per month.

Unmet_Orders = DELAY(ORDERS_LAST_MONTH,1,0)-Total_Selling

DOCUMENT: Number of unmet orders.

Economy_Factor = GRAPH(Oil_Price)

(0.00, 0.00), (11.0, 0.4), (22.0, 1.12), (33.0, 0.8), (44.0, 0.6), (55.0, 0.3), (66.0, 0.2), (77.0, 0.1), (88.0, 0.05), (99.0, 0.025), (110, 0.00)

DOCUMENT: Effect of Oil price on Economy.

History_Factor = GRAPH(Unmet_Orders)

(0.00, 1.10), (50.0, 0.9), (100, 0.5), (150, 0.3), (200, 0.2)

DOCUMENT: Factor that shows the effect of unmet orders in generating new orders for the company.

Price_Factor150 = GRAPH(Distributor_Price_Change150)

(-150, 1.05), (-120, 1.04), (-90.0, 1.03), (-60.0, 1.02), (-30.0, 1.01), (0.00, 1.00), (30.0, 0.95), (60.0, 0.9), (90.0, 0.9), (120, 0.85), (150, 0.8)

Price_Factor600 = GRAPH(Distributor_Price_Change600)

(-650, 1.05), (-520, 1.04), (-390, 1.03), (-260, 1.02), (-130, 1.01), (0.00, 1.00), (130, 0.95), (260, 0.9), (390, 0.9), (520, 0.85), (650, 0.8)

Price_Factor_300 = GRAPH(Distributor_Price_Change_300)

(-250, 1.05), (-200, 1.04), (-150, 1.03), (-100, 1.02), (-50.0, 1.01), (0.00, 1.00), (50.0, 0.95), (100, 0.9), (150, 0.9), (200, 0.85), (250, 0.8)

Price_Factor_SO = GRAPH(Distributor_Price_Change_SO)

(-1000, 1.05), (-800, 1.04), (-600, 1.03), (-400, 1.02), (-200, 1.01), (0.00, 1.00), (200, 0.95), (400, 0.9), (600, 0.9), (800, 0.85), (1000, 0.8)

P. L. ANSI 150

FINISHED_150(t) = FINISHED_150(t - dt) + (Assembling_150 - Selling_150) * dt

INIT FINISHED_150 = 0

INFLOWS:

Assembling_150 =
IF(LABOR_150*Productivity_150)>=Completing_150_orders_for_Assembling
THEN(Completing_150_orders_for_Assembling)ELSE(Productivity_150*LABOR_150)

DOCUMENT: Assembling machined material per month.

OUTFLOWS:

Selling_150 = FINISHED_150

LABOR_150(t) = LABOR_150(t - dt)

INIT LABOR_150 = 5

MACHINED_MATERIAL_ON_ORDER_150(t) =
MACHINED_MATERIAL_ON_ORDER_150(t - dt) + (Material_ordering_150 - Receiving_machined_material_150) * dt

INIT MACHINED_MATERIAL_ON_ORDER_150 = 0

TRANSIT TIME = varies

INFLOW LIMIT = INF

CAPACITY = INF

INFLOWS:

Material_ordering_150 =
PULSE(Order_signal_150*Order_size_150*Cash_Availabilty_Factor,1,1)

DOCUMENT: Ordering rate of finished material when the finished inventory level is less than the threshold value.

OUTFLOWS:

Receiving_machined_material_150 = CONVEYOR OUTFLOW

TRANSIT TIME = Supplier_Delivery_Time

DOCUMENT: Receiving finished material per month.

MC_MATERIAL_INVENTORY_150(t) = MC_MATERIAL_INVENTORY_150(t - dt) + (Receiving_machined_material_150 - Assembling_150 - Scrapping_150) * dt

INIT MC_MATERIAL_INVENTORY_150 = 210

DOCUMENT: Inventory of machined material (Numbers).

INFLOWS:

Receiving_machined_material_150 = CONVEYOR OUTFLOW

TRANSIT TIME = Supplier_Delivery_Time

DOCUMENT: Receiving finished material per month.

OUTFLOWS:

Assembling_150 =
IF(LABOR_150*Productivity_150)>=Completing_150_orders_for_Assembling
THEN(Completing_150_orders_for_Assembling)ELSE(Productivity_150*LABOR_150)

DOCUMENT: Assembling machined material per month.

Scrapping_150 = Scrap_Rate_150

ORDERS_150(t) = ORDERS_150(t - dt) + (Ordering_150 - Completing_150_orders_for_Assembling) * dt

INIT ORDERS_150 = 70

DOCUMENT: Number of orders

INFLOWS:

Ordering_150 = NORMAL(ANSI_150_ordering_Rate,15,150)

DOCUMENT: Order of class 600 per month.

OUTFLOWS:

Completing_150_orders_for_Assembling = ORDERS_150

DOCUMENT: Orders clearing per month.

Major_Cont_Capacity_150 = 100

Order_signal_150 = if Total_supply_line_inventory_150 < Order_threshold_150 then 1 else 0

DOCUMENT: The order signal says, "Order supplies whenever the total supply line inventory falls below the threshold value."

Order_size_150 = IF(Major_Cont_Capacity_150>=ANSI_150_ordering_Rate)THEN(ANSI_150_ordering_Rate*2)ELSE(ANSI_150_ordering_Rate+Major_Cont_Capacity_150)

Order_threshold_150 = 210

DOCUMENT: What level of raw materials inventory--including both what's currently in your inventory and what's currently on order--is the threshold for ordering additional raw materials from your supplier? When you go below the threshold, the order signal will get generated.

Productivity_150 = 30

Scrap_Rate_150 = Scrap_Rate*FINISHED_150

Total_supply_line_inventory_150 =
MACHINED_MATERIAL_ON_ORDER_150+MC_MATERIAL_INVENTORY_150

DOCUMENT: the total supply line inventory is the sum of the raw materials on order and the raw materials in hand.

P. L. Special Orders

FINISHED_SO(t) = FINISHED_SO(t - dt) + (Assembling_SO - Selling_SO) * dt

INIT FINISHED_SO = 0

INFLOWS:

Assembling_SO = IF(LABOR_SO*Productivity_SO)>CompletingSO_for_Assembling THEN(CompletingSO_for_Assembling)ELSE(Productivity_SO*LABOR_SO)

DOCUMENT: Assembling machined material per month.

OUTFLOWS:

Selling_SO = FINISHED_SO

LABOR_SO(t) = LABOR_SO(t - dt)

INIT LABOR_SO = 5

MC_MATERIAL_INVENTORY_SO(t) = MC_MATERIAL_INVENTORY_SO(t - dt) + (receiving_machined_material_SO - Assembling_SO - Scrapping_SO) * dt

INIT MC_MATERIAL_INVENTORY_SO = 0

DOCUMENT: Inventory of machined material (Numbers).

INFLOWS:

receiving_machined_material_SO = CONVEYOR OUTFLOW

TRANSIT TIME = Supplier_Delivery_Time_SO

DOCUMENT: Receiving finished material per month.

OUTFLOWS:

Assembling_SO = IF(LABOR_SO*Productivity_SO)>CompletingSO_for_Assembling THEN(CompletingSO_for_Assembling)ELSE(Productivity_SO*LABOR_SO)

DOCUMENT: Assembling machined material per month.

Scrapping_SO = Scrap_Rate_SO

SPECIAL_MACHINED_MATERIAL_ON_ORDER(t) = SPECIAL_MACHINED_MATERIAL_ON_ORDER(t - dt) + (Material_ordering_SO - receiving_machined_material_SO) * dt

INIT SPECIAL_MACHINED_MATERIAL_ON_ORDER = 0

TRANSIT TIME = varies

INFLOW LIMIT = INF

CAPACITY = INF

DOCUMENT: 0

INFLOWS:

Material_ordering_SO = Order_size_SO*Cash_Availabilty_Factor

DOCUMENT: Ordering rate of finished material when the finished inventory level is less than the threshold value.

OUTFLOWS:

receiving_machined_material_SO = CONVEYOR OUTFLOW

TRANSIT TIME = Supplier_Delivery_Time_SO

DOCUMENT: Receiving finished material per month.

SPECIAL_ORDERS(t) = SPECIAL_ORDERS(t - dt) + (Ordering_SO - CompletingSO_for_Assembling) * dt

INIT SPECIAL_ORDERS = 10

DOCUMENT: Number of orders

INFLOWS:

Ordering_SO = NORMAL(Special_oders,5,400)

DOCUMENT: Order of class Special orders per month.

OUTFLOWS:

CompletingSO_for_Assembling = SPECIAL_ORDERS

DOCUMENT: Orders clearing per month.

Order_size_SO = Special_oders

Productivity_SO = 30

Scrap_Rate_SO = Scrap_Rate*FINISHED_SO

Supplier_Delivery_Time_SO = 4

DOCUMENT: Time taken by supplier to deliver the finished material (Months).

P.L. ANSI 300

FINISHED_300(t) = FINISHED_300(t - dt) + (Assembling_300 - Selling_300) * dt

INIT FINISHED_300 = 0

INFLOWS:

Assembling_300 =
IF(LABOR_300*Productivity_300)>=Completing_300_orders_for_Assembling
THEN(Completing_300_orders_for_Assembling)ELSE(Productivity_300*LABOR_300)

DOCUMENT: Assembling machined material per month.

OUTFLOWS:

Selling_300 = FINISHED_300

LABOR_300(t) = LABOR_300(t - dt)

INIT LABOR_300 = 5

MACHINED_MATERIAL_ON_ORDER_300(t) =
MACHINED_MATERIAL_ON_ORDER_300(t - dt) + (Material_ordering_300 -
Receiving_machined_material_300) * dt

INIT MACHINED_MATERIAL_ON_ORDER_300 = 0

TRANSIT TIME = varies

INFLOW LIMIT = INF

CAPACITY = INF

INFLOWS:

Material_ordering_300 =
PULSE(Order_signal_300*Order_size_300*Cash_Availabilty_Factor,1,1)

DOCUMENT: Ordering rate of finished material when the finished inventory level is less than the threshold value.

OUTFLOWS:

Receiving_machined_material_300 = CONVEYOR OUTFLOW

TRANSIT TIME = Supplier_Delivery_Time

DOCUMENT: Receiving finished material per month.

MC_MATERIAL_INVENTORY_300(t) = MC_MATERIAL_INVENTORY_300(t - dt)
+ (Receiving_machined_material_300 - Assembling_300 - Scrapping_300) * dt

INIT MC_MATERIAL_INVENTORY_300 = 50

DOCUMENT: Inventory of machined material (Numbers).

INFLOWS:

Receiving_machined_material_300 = CONVEYOR OUTFLOW

TRANSIT TIME = Supplier_Delivery_Time

DOCUMENT: Receiving finished material per month.

OUTFLOWS:

Assembling_300 =
IF(LABOR_300*Productivity_300)>=Completing_300_orders_for_Assembling
THEN(Completing_300_orders_for_Assembling)ELSE(Productivity_300*LABOR_300)

DOCUMENT: Assembling machined material per month.

Scrapping_300 = Scrap_Rate_300

ORDERS_300(t) = ORDERS_300(t - dt) + (Ordering_300 - Completing_300_orders_for_Assembling) * dt

INIT ORDERS_300 = 10

DOCUMENT: Number of orders

INFLOWS:

Ordering_300 = NORMAL(ANSI_300_ordering_Rate,5,300)

DOCUMENT: Order of class 300 per month.

OUTFLOWS:

Completing_300_orders_for_Assembling = ORDERS_300

DOCUMENT: Orders clearing per month.

Major_Cont_Capacity_300 = 30

Order_signal_300 = if Total_supply_line_inventory_300 < Order_threshold_300 then 1 else 0

DOCUMENT: The order signal says, "Order supplies whenever the total supply line inventory falls below the threshold value."

Order_size_300 = IF(Major_Cont_Capacity_300>=ANSI_300_ordering_Rate)THEN(ANSI_300_ordering_Rate*2)ELSE(ANSI_300_ordering_Rate+Major_Cont_Capacity_300)

Order_threshold_300 = 30

DOCUMENT: What level of raw materials inventory--including both what's currently in your inventory and what's currently on order--is the threshold for ordering additional raw materials from your supplier? When you go below the threshold, the order signal will get generated.

Productivity_300 = 30

Scrap_Rate = .01

Scrap_Rate_300 = Scrap_Rate*FINISHED_300

Total_supply_line_inventory_300 =
MACHINED_MATERIAL_ON_ORDER_300+MC_MATERIAL_INVENTORY_300

DOCUMENT: the total supply line inventory is the sum of the raw materials on order and the raw materials in hand.

P.L. ANSI 600

FINISHED_600(t) = FINISHED_600(t - dt) + (Assembling_600 - Selling_600) * dt

INIT FINISHED_600 = 0

DOCUMENT: Number of finished products

INFLOWS:

Assembling_600 =
IF(LABOR_600*Productivity_600)>=Completing_600_orders_for_Assembling
THEN(Completing_600_orders_for_Assembling)ELSE(Productivity_600*LABOR_600)

DOCUMENT: Assembling machined material per month.

OUTFLOWS:

Selling_600 = FINISHED_600

DOCUMENT: Units of product selling per month.

LABOR_600(t) = LABOR_600(t - dt)

INIT LABOR_600 = 5

DOCUMENT: Number of workers available to assemble.

MACHINED_MATERIAL_ON_ORDER_600(t) = MACHINED_MATERIAL_ON_ORDER_600(t - dt) + (Material_ordering_600 - Receiving_machined_material_600) * dt

INIT MACHINED_MATERIAL_ON_ORDER_600 = 0

TRANSIT TIME = varies

INFLOW LIMIT = INF

CAPACITY = INF

INFLOWS:

Material_ordering_600 = PULSE(Order_signal_600*Order_size_600*Cash_Availabilty_Factor,1,1)

DOCUMENT: Ordering rate of finished material when the finished inventory level is less than the threshold value.

OUTFLOWS:

Receiving_machined_material_600 = CONVEYOR OUTFLOW

TRANSIT TIME = Supplier_Delivery_Time

DOCUMENT: Receiving finished material per month.

MC_MATERIAL_INVENTORY_600(t) = MC_MATERIAL_INVENTORY_600(t - dt) + (Receiving_machined_material_600 - Assembling_600 - Scrapping_600) * dt

INIT MC_MATERIAL_INVENTORY_600 = 90

DOCUMENT: Inventory of machined material.

INFLOWS:

Receiving_machined_material_600 = CONVEYOR OUTFLOW

TRANSIT TIME = Supplier_Delivery_Time

DOCUMENT: Receiving finished material per month.

OUTFLOWS:

Assembling_600 =
IF(LABOR_600*Productivity_600)>=Completing_600_orders_for_Assembling
THEN(Completing_600_orders_for_Assembling)ELSE(Productivity_600*LABOR_600)

DOCUMENT: Assembling machined material per month.

Scrapping_600 = Scrap_Rate600

DOCUMENT: Number of products scrapped per month.

ORDERS_600(t) = ORDERS_600(t - dt) + (Ordering_600 - Completing_600_orders_for_Assembling) * dt

INIT ORDERS_600 = 30

DOCUMENT: Number of orders.

INFLOWS:

Ordering_600 = NORMAL(ANSI_600_ordering_Rate,10,600)

DOCUMENT: Order of class 600 per month.

OUTFLOWS:

Completing_600_orders_for_Assembling = ORDERS_600

DOCUMENT: Orders clearing per month.

Major_Cont_Capacity_600 = 60

Order_signal_600 = if Total_supply_line_inventory_600 < Order_threshold_600 then 1 else 0

DOCUMENT: The order signal says, "Order supplies whenever the total supply line inventory falls below the threshold value."

Order_size_600 = IF(Major_Cont_Capacity_600>=ANSI_600_ordering_Rate)THEN(ANSI_600_ordering_Rate*2)ELSE(Major_Cont_Capacity_600+ANSI_600_ordering_Rate)

DOCUMENT: Size of order to be ordered from supplier for machined material.

Order_threshold_600 = 90

DOCUMENT: What level of raw materials inventory--including both what's currently in your inventory and what's currently on order--is the threshold for ordering additional raw materials from your supplier? When you go below the threshold, the order signal will get generated.

Productivity_600 = 30

DOCUMENT: Number of products produced by a worker per month.

Scrap_Rate600 = Scrap_Rate*FINISHED_600

DOCUMENT: The amount of scrap produced.

Supplier_Delivery_Time = 3

DOCUMENT: Time taken by supplier to deliver the finished material (M).

Total_supply_line_inventory_600 =
MACHINED_MATERIAL_ON_ORDER_600+MC_MATERIAL_INVENTORY_600

DOCUMENT: the total supply line inventory is the sum of the raw materials on order and the raw materials in hand.

Raw Material Cost Sector

Change_in_Raw_MaterialPercentage = 0

Raw_Material_Percentage = .2+Change_in_Raw_MaterialPercentage

Total_Raw_Material_Cost =
((Average_Special_order_price*receiving_machined_material_SO)+(ANSI_150_price*Receiving_machined_material_150)+(Receiving_machined_material_300*ANSI_300_price)+(Receiving_machined_material_600*ANSI_600_price))*Raw_Material_Percentage

DOCUMENT: Total raw material cost in dollars per month (Dollars/Month).

Appendix C: Debug Table

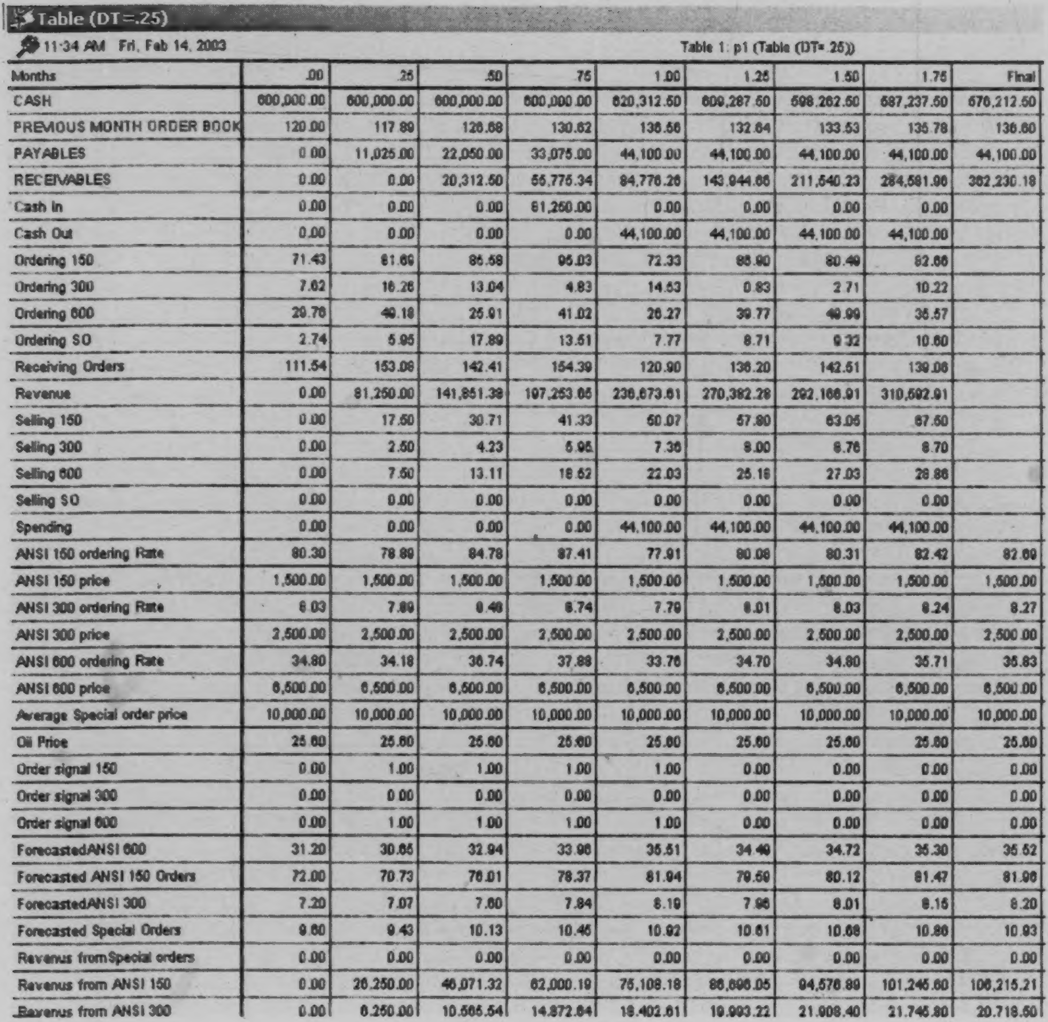


Table (DT=.25)

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Table 1: p1 (Table (DT=.25))

Months	.00	.25	.50	.75	1.00	1.25	1.50	1.75	Final
CASH	600,000.00	600,000.00	600,000.00	600,000.00	620,312.50	609,287.50	598,262.50	587,237.50	576,212.50
PREVIOUS MONTH ORDER BOOK	120.00	117.89	126.68	130.62	136.56	132.64	133.53	135.78	136.60
PAYABLES	0.00	11,025.00	22,050.00	33,075.00	44,100.00	44,100.00	44,100.00	44,100.00	44,100.00
RECEIVABLES	0.00	0.00	20,312.50	56,775.34	84,776.26	143,944.66	211,540.23	284,581.96	362,230.18
Cash In	0.00	0.00	0.00	61,250.00	0.00	0.00	0.00	0.00	
Cash Out	0.00	0.00	0.00	0.00	44,100.00	44,100.00	44,100.00	44,100.00	
Ordering 150	71.43	81.69	86.58	95.03	72.33	85.90	80.49	82.66	
Ordering 300	7.62	16.26	13.04	4.83	14.53	0.83	2.71	10.22	
Ordering 600	29.76	49.18	25.91	41.02	26.27	39.77	49.99	36.57	
Ordering SO	2.74	5.95	17.89	13.51	7.77	8.71	9.32	10.60	
Receiving Orders	111.54	153.06	142.41	154.39	120.90	136.20	142.51	139.06	
Revenue	0.00	81,250.00	141,851.38	197,253.06	236,673.61	270,382.28	292,166.91	310,592.91	
Selling 150	0.00	17.50	30.71	41.33	50.07	57.80	63.05	67.50	
Selling 300	0.00	2.50	4.23	5.95	7.36	8.00	8.76	8.70	
Selling 600	0.00	7.50	13.11	18.62	22.03	25.16	27.03	28.86	
Selling SO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Spending	0.00	0.00	0.00	0.00	44,100.00	44,100.00	44,100.00	44,100.00	
ANSI 150 ordering Rate	80.30	78.89	84.78	87.41	77.91	80.08	80.31	82.42	82.69
ANSI 150 price	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00
ANSI 300 ordering Rate	8.03	7.89	8.48	8.74	7.79	8.01	8.03	8.24	8.27
ANSI 300 price	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00
ANSI 600 ordering Rate	34.80	34.18	36.74	37.88	33.76	34.70	34.80	35.71	35.83
ANSI 600 price	6,500.00	6,500.00	6,500.00	6,500.00	6,500.00	6,500.00	6,500.00	6,500.00	6,500.00
Average Special order price	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00
Oil Price	25.60	25.60	25.60	25.60	25.60	25.60	25.60	25.60	25.60
Order signal 150	0.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
Order signal 300	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Order signal 600	0.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
ForecastedANSI 600	31.20	30.65	32.94	33.96	35.51	34.49	34.72	35.30	35.52
Forecasted ANSI 150 Orders	72.00	70.73	76.01	78.37	81.94	79.59	80.12	81.47	81.96
ForecastedANSI 300	7.20	7.07	7.60	7.84	8.19	7.96	8.01	8.15	8.20
Forecasted Special Orders	9.60	9.43	10.13	10.45	10.92	10.61	10.68	10.86	10.93
Revenus fromSpecial orders	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Revenus from ANSI 150	0.00	26,250.00	46,071.32	62,000.19	75,108.18	86,696.05	94,576.89	101,246.60	106,215.21
Revenus from ANSI 300	0.00	6,250.00	10,565.54	14,872.84	18,402.61	19,993.22	21,908.40	21,745.80	20,718.50

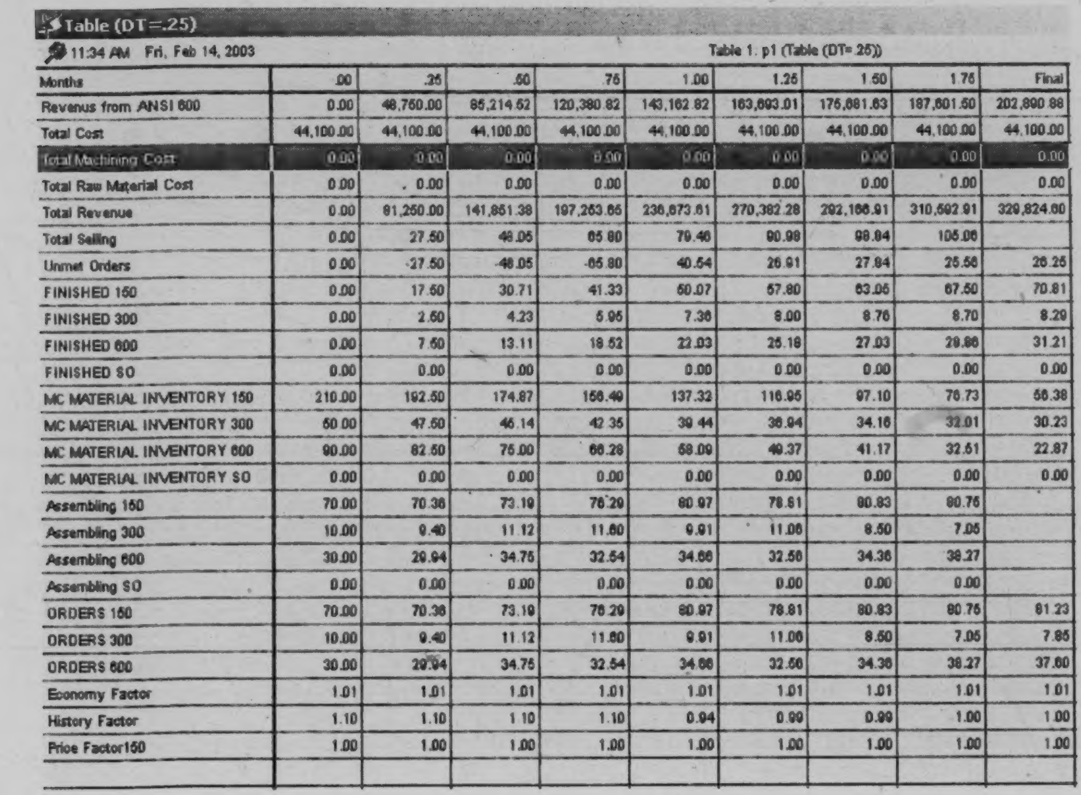

Table (DT=.25)

11:34 AM Fri, Feb 14, 2003

Table 1: p1 (Table (DT=.25))

Months	.00	.25	.50	.75	1.00	1.25	1.50	1.75	Final
Revenus from ANSI 600	0.00	48,750.00	85,214.52	120,380.82	143,162.82	163,693.01	175,681.63	187,601.50	202,890.88
Total Cost	44,100.00	44,100.00	44,100.00	44,100.00	44,100.00	44,100.00	44,100.00	44,100.00	44,100.00
Total Machining Cost	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Raw Material Cost	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Revenue	0.00	81,250.00	141,851.38	197,253.65	236,873.61	270,382.28	292,166.91	310,592.91	329,824.60
Total Selling	0.00	27.50	48.05	65.80	79.46	90.98	98.84	105.06	
Unmet Orders	0.00	-27.50	-48.05	-65.80	40.54	26.91	27.84	25.56	26.25
FINISHED 150	0.00	17.50	30.71	41.33	50.07	57.80	63.05	67.50	70.81
FINISHED 300	0.00	2.50	4.23	5.95	7.36	8.00	8.76	8.70	8.29
FINISHED 600	0.00	7.50	13.11	18.52	22.03	25.16	27.03	29.86	31.21
FINISHED SO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MC MATERIAL INVENTORY 150	210.00	192.50	174.87	156.49	137.32	116.95	97.10	76.73	56.38
MC MATERIAL INVENTORY 300	50.00	47.50	46.14	42.35	39.44	36.94	34.16	32.01	30.23
MC MATERIAL INVENTORY 600	90.00	82.50	75.00	66.26	58.09	49.37	41.17	32.61	22.87
MC MATERIAL INVENTORY SO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Assembling 150	70.00	70.36	73.19	76.29	80.97	78.81	80.83	80.75	
Assembling 300	10.00	9.40	11.12	11.60	9.91	11.06	8.50	7.05	
Assembling 600	30.00	29.94	34.75	32.54	34.66	32.56	34.36	38.27	
Assembling SO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
ORDERS 150	70.00	70.36	73.19	76.29	80.97	78.81	80.83	80.75	81.23
ORDERS 300	10.00	9.40	11.12	11.60	9.91	11.06	8.50	7.05	7.85
ORDERS 600	30.00	29.94	34.75	32.54	34.66	32.56	34.36	38.27	37.60
Economy Factor	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
History Factor	1.10	1.10	1.10	1.10	0.94	0.99	0.99	1.00	1.00
Price Factor150	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

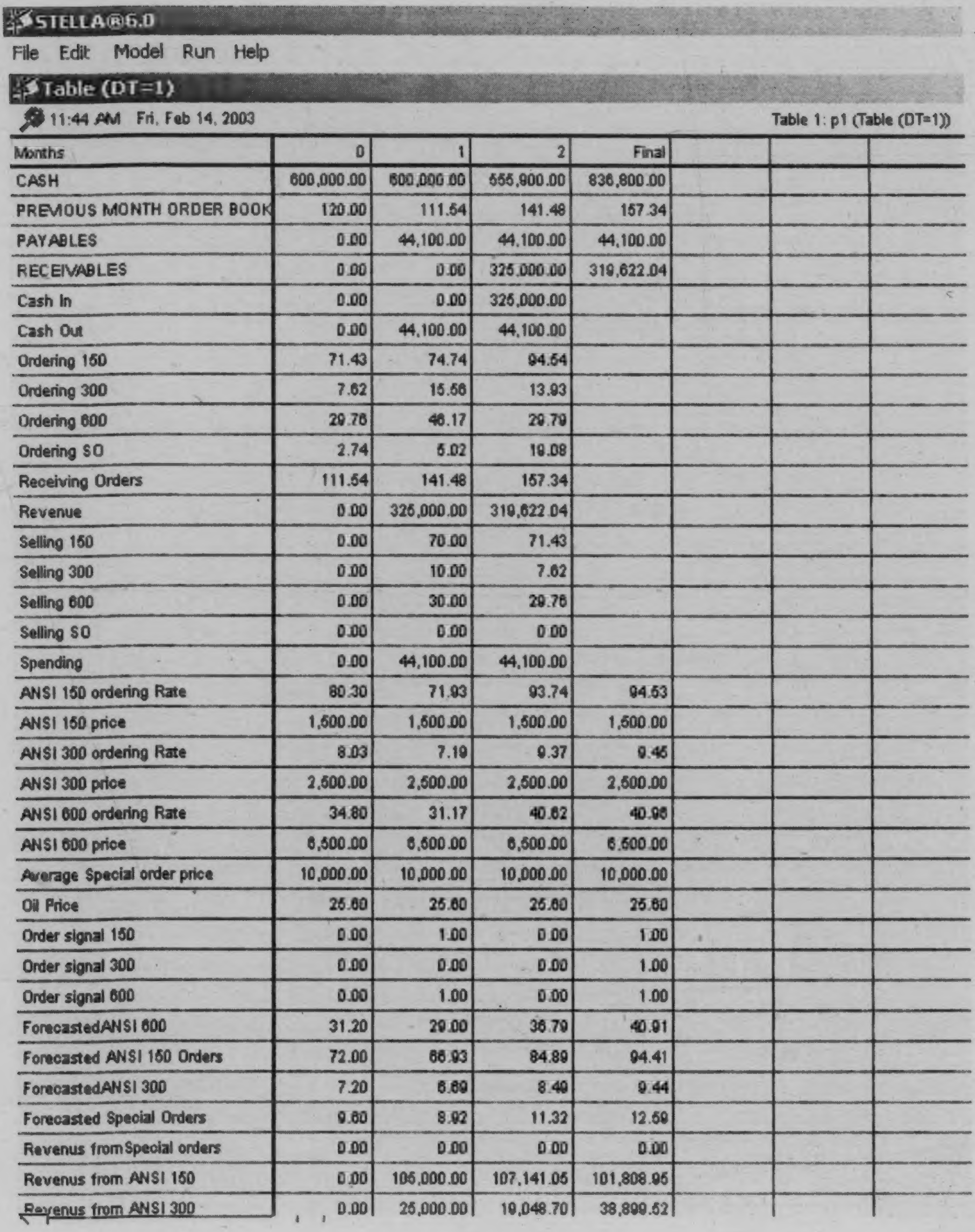

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Table 1: p1 (Table (DT=1))

Months	0	1	2	Final
CASH	600,000.00	600,000.00	555,900.00	836,800.00
PREVIOUS MONTH ORDER BOOK	120.00	111.54	141.48	157.34
PAYABLES	0.00	44,100.00	44,100.00	44,100.00
RECEIVABLES	0.00	0.00	325,000.00	319,622.04
Cash In	0.00	0.00	325,000.00	
Cash Out	0.00	44,100.00	44,100.00	
Ordering 150	71.43	74.74	94.54	
Ordering 300	7.62	15.56	13.93	
Ordering 600	29.76	46.17	29.79	
Ordering SO	2.74	5.02	19.08	
Receiving Orders	111.54	141.48	157.34	
Revenue	0.00	325,000.00	319,622.04	
Selling 150	0.00	70.00	71.43	
Selling 300	0.00	10.00	7.62	
Selling 600	0.00	30.00	29.76	
Selling SO	0.00	0.00	0.00	
Spending	0.00	44,100.00	44,100.00	
ANSI 150 ordering Rate	80.30	71.93	93.74	94.53
ANSI 150 price	1,500.00	1,500.00	1,500.00	1,500.00
ANSI 300 ordering Rate	8.03	7.19	9.37	9.45
ANSI 300 price	2,500.00	2,500.00	2,500.00	2,500.00
ANSI 600 ordering Rate	34.80	31.17	40.62	40.96
ANSI 600 price	6,500.00	6,500.00	6,500.00	6,500.00
Average Special order price	10,000.00	10,000.00	10,000.00	10,000.00
Oil Price	25.60	25.60	25.60	25.60
Order signal 150	0.00	1.00	0.00	1.00
Order signal 300	0.00	0.00	0.00	1.00
Order signal 600	0.00	1.00	0.00	1.00
ForecastedANSI 600	31.20	29.00	36.79	40.91
Forecasted ANSI 150 Orders	72.00	66.93	84.89	94.41
ForecastedANSI 300	7.20	6.69	8.49	9.44
Forecasted Special Orders	9.60	8.92	11.32	12.59
Revenus from Special orders	0.00	0.00	0.00	0.00
Revenus from ANSI 150	0.00	105,000.00	107,141.05	101,808.95
Revenus from ANSI 300	0.00	25,000.00	19,048.70	38,899.52

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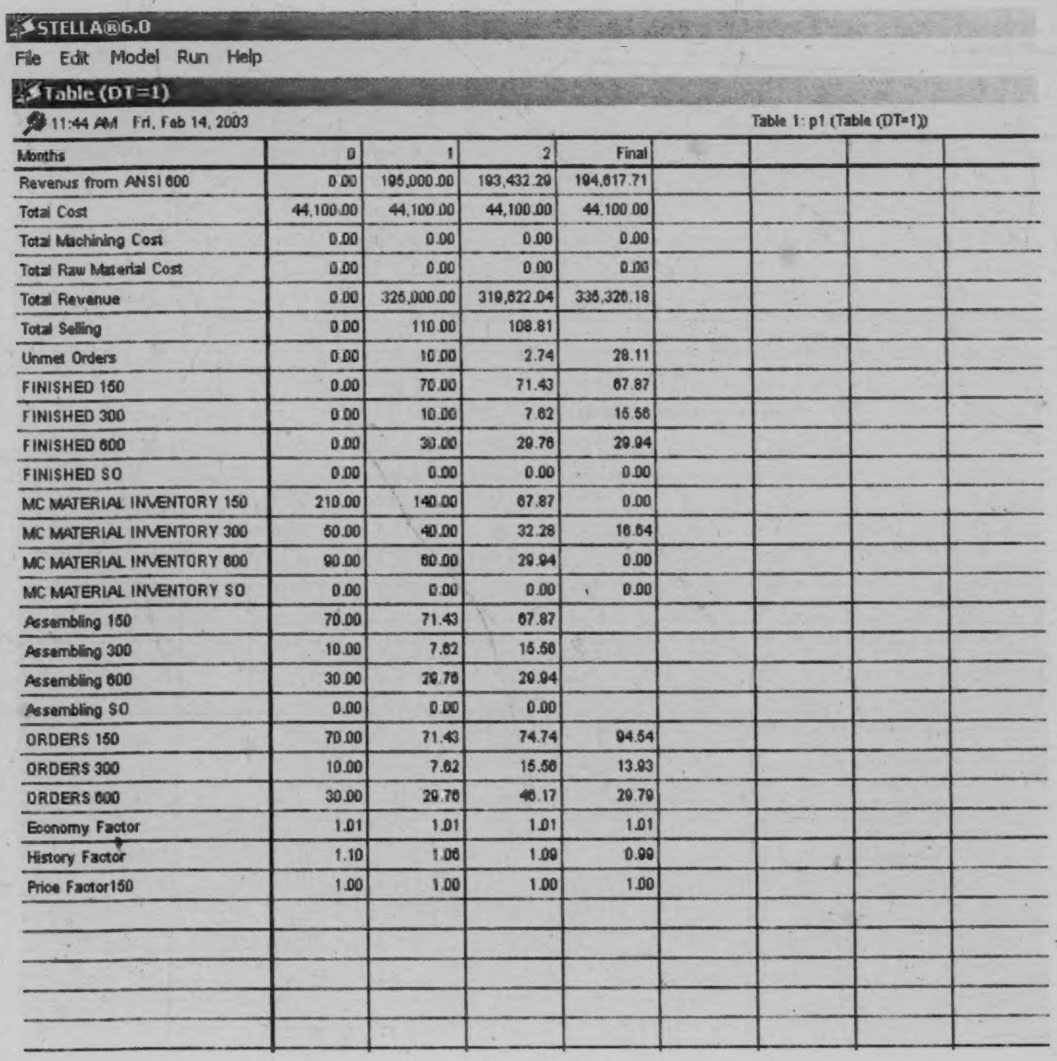

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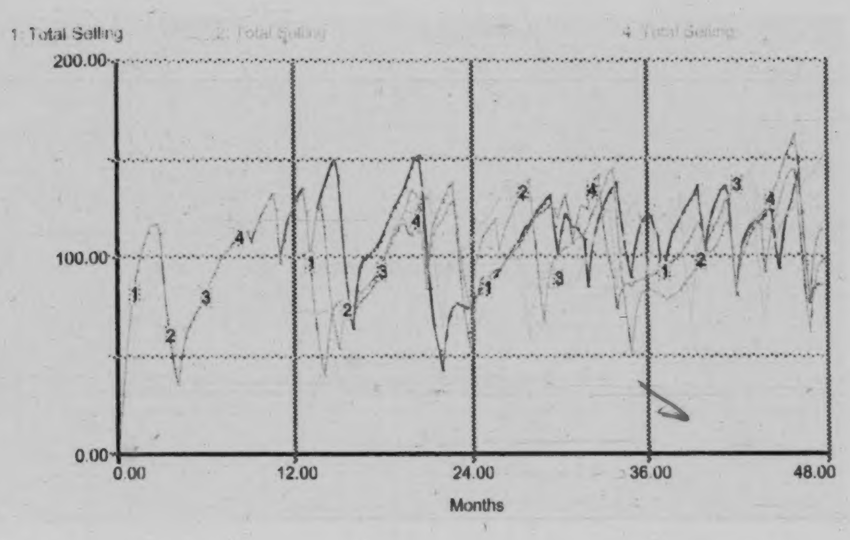
Table 1: p1 (Table (DT=1))

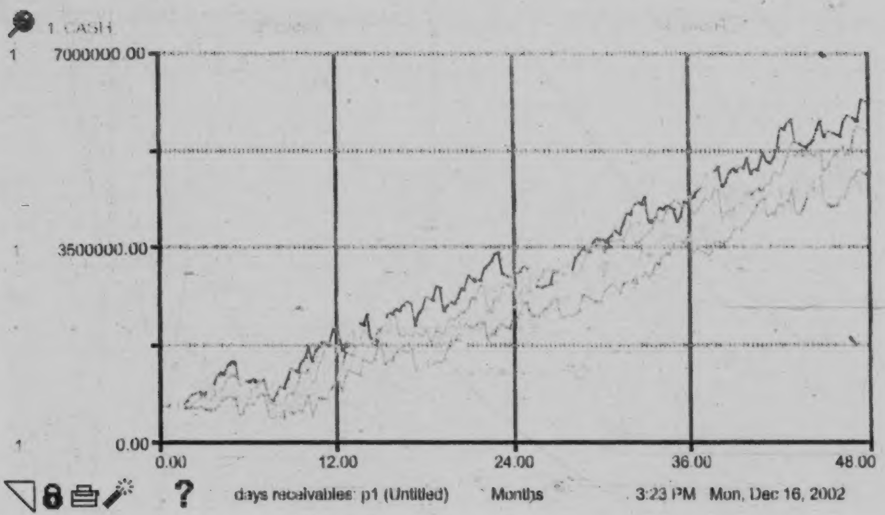
Months	0	1	2	Final
Revenus from ANSI 600	0.00	195,000.00	193,432.29	194,617.71
Total Cost	44,100.00	44,100.00	44,100.00	44,100.00
Total Machining Cost	0.00	0.00	0.00	0.00
Total Raw Material Cost	0.00	0.00	0.00	0.00
Total Revenue	0.00	325,000.00	319,622.04	336,326.18
Total Selling	0.00	110.00	108.81	
Unmet Orders	0.00	10.00	2.74	28.11
FINISHED 150	0.00	70.00	71.43	67.87
FINISHED 300	0.00	10.00	7.62	15.56
FINISHED 600	0.00	30.00	29.76	29.94
FINISHED SO	0.00	0.00	0.00	0.00
MC MATERIAL INVENTORY 150	210.00	140.00	67.87	0.00
MC MATERIAL INVENTORY 300	50.00	40.00	32.28	16.64
MC MATERIAL INVENTORY 600	90.00	60.00	29.94	0.00
MC MATERIAL INVENTORY SO	0.00	0.00	0.00	0.00
Assembling 150	70.00	71.43	67.87	
Assembling 300	10.00	7.62	15.56	
Assembling 600	30.00	29.76	29.94	
Assembling SO	0.00	0.00	0.00	
ORDERS 150	70.00	71.43	74.74	94.54
ORDERS 300	10.00	7.62	15.56	13.93
ORDERS 600	30.00	29.76	46.17	29.79
Economy Factor	1.01	1.01	1.01	1.01
History Factor	1.10	1.06	1.09	0.99
Price Factor150	1.00	1.00	1.00	1.00

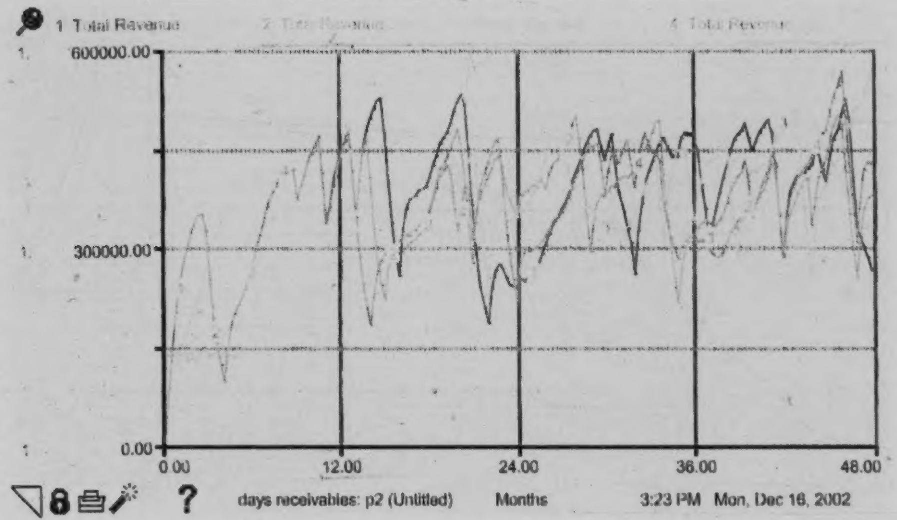
Appendix D

Days of Receivables

Run #	Days of Receivables (Days)
Run #1	30
Run #2	50
Run #3	70
Run #4	90

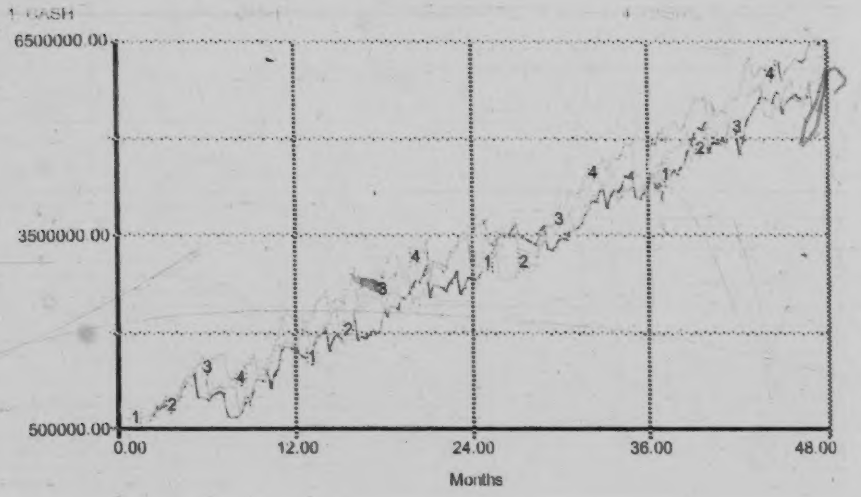


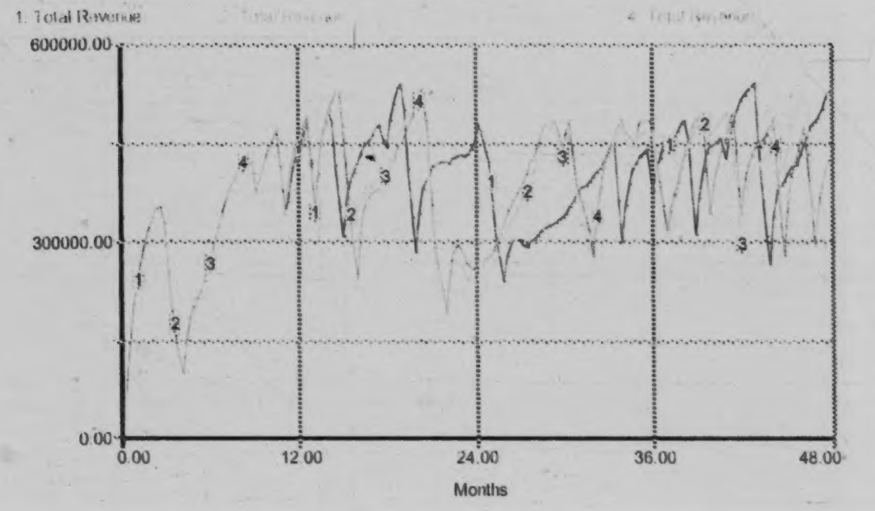


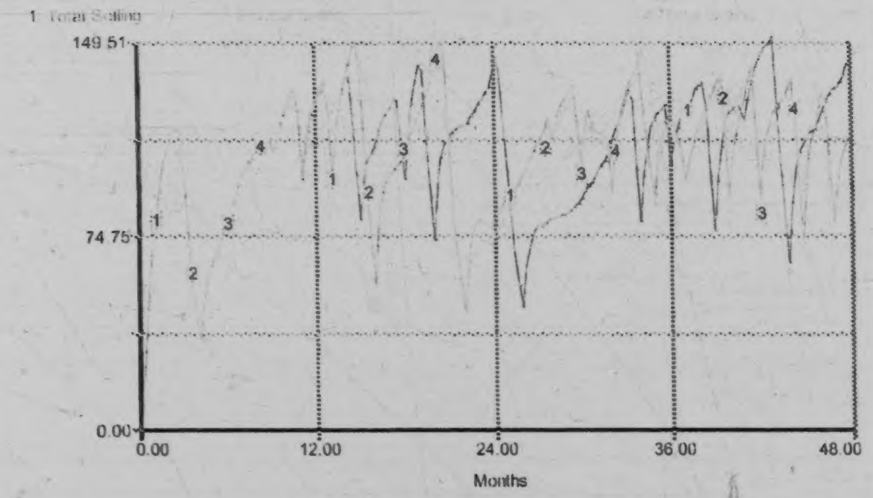


Days of Payables

Run #	Days of Payable (Days)
Run #1	30
Run #2	50
Run #3	70
Run #4	90

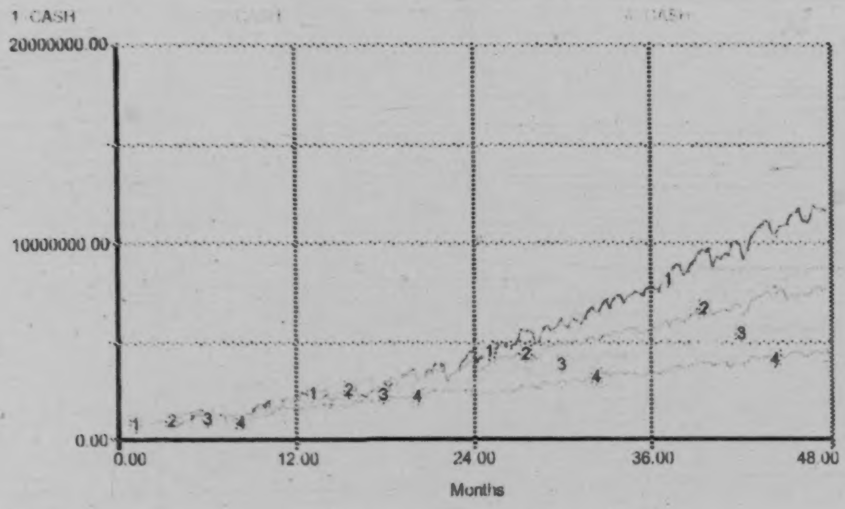

1: CASH
2: CASH
4: CASH
6500000.00
3500000.00
500000.00
0.00
12.00
24.00
36.00
48.00
Months
1
2
3
4

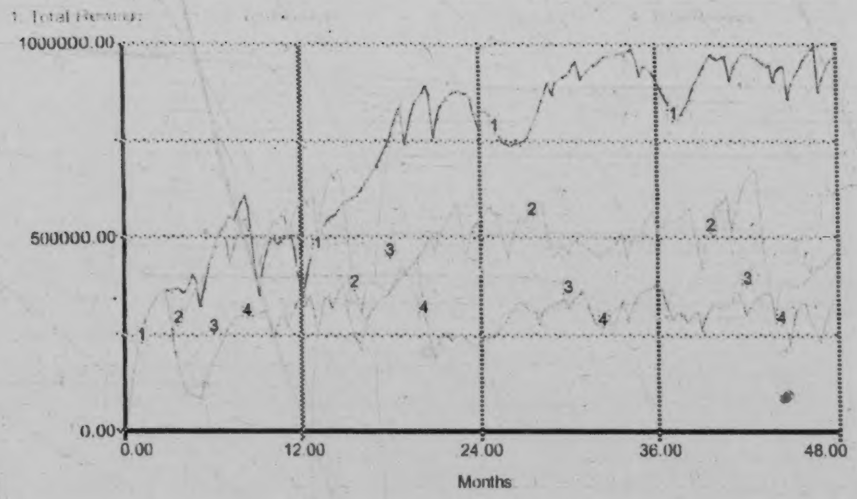

1. Total Revenue
2: Total Revenue
4: Total Revenue
600000.00
300000.00
0.00
0.00
12.00
24.00
36.00
48.00
Months
1
2
3
4

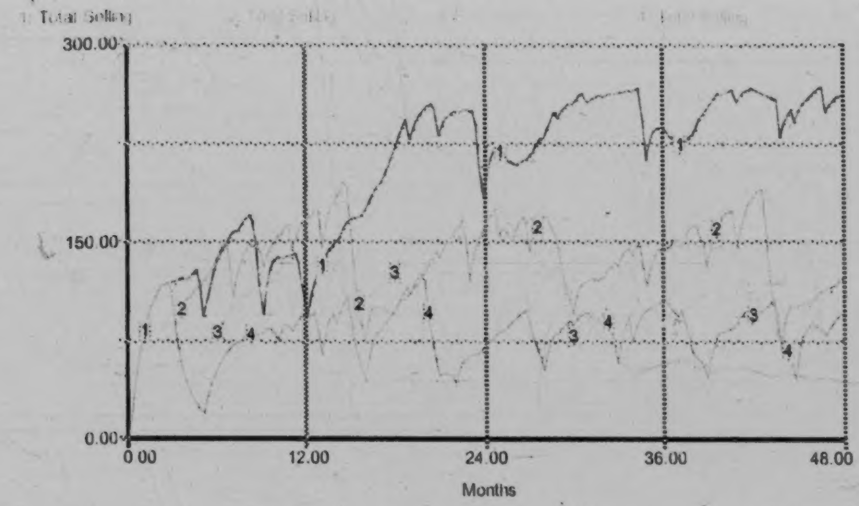


Supplier delivery Time

Run #	Supplier Delivery Time (Days)
Run #1	30
Run #2	60
Run #3	90
Run #4	120

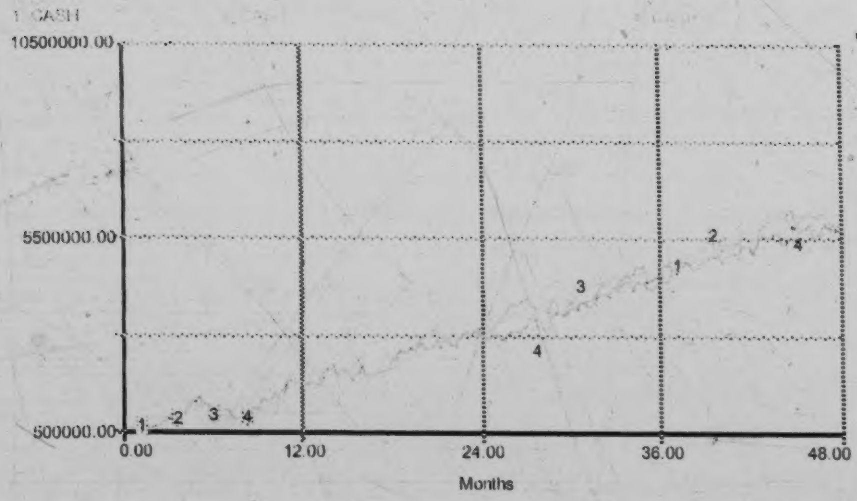


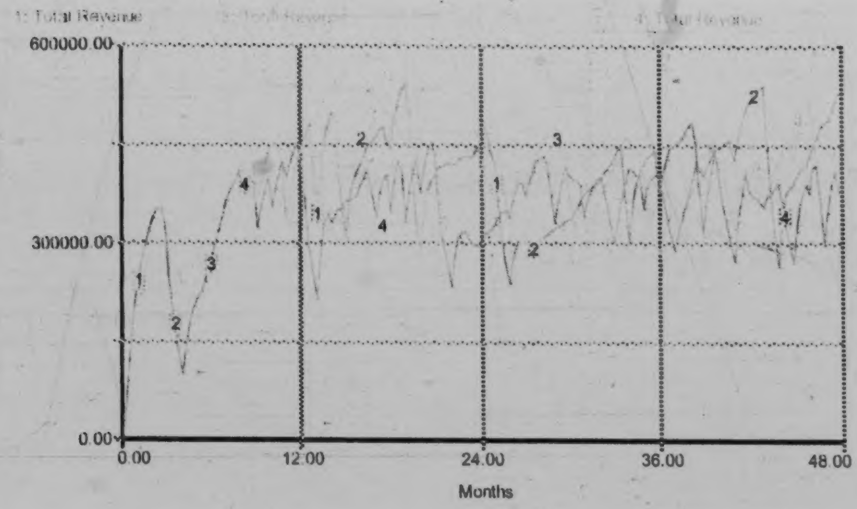


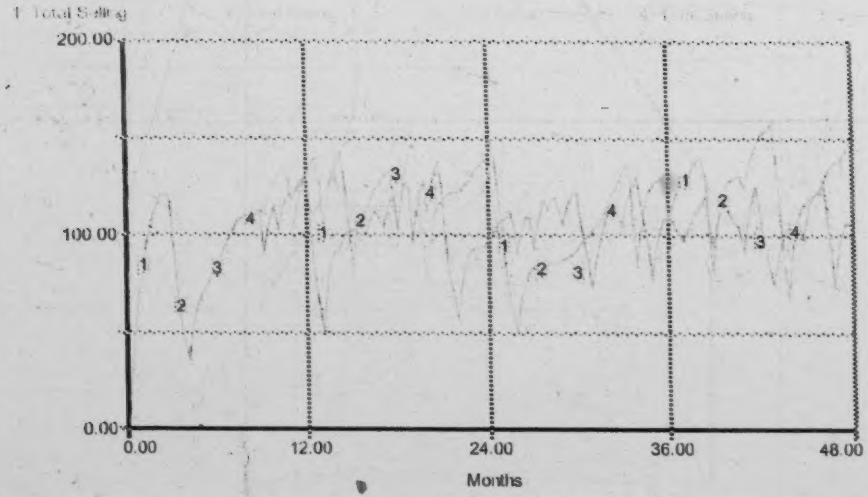


Major Contractor Capacity

Run #	Major Contractor Capacity for ANSI 150	Major Contractor Capacity for ANSI 300	Major Contractor Capacity for ANSI 600
Run #1	200	60	120
Run #2	133	40	80
Run #3	67	20	40
Run #4	0	0	0

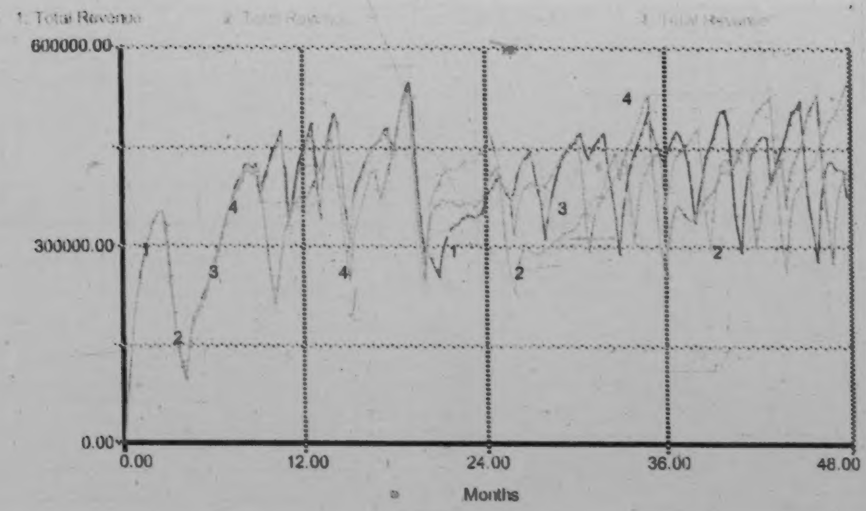

1: CASH
10500000.00
5500000.00
500000.00
1
2
3
4
0.00
12.00
24.00
36.00
48.00
Months

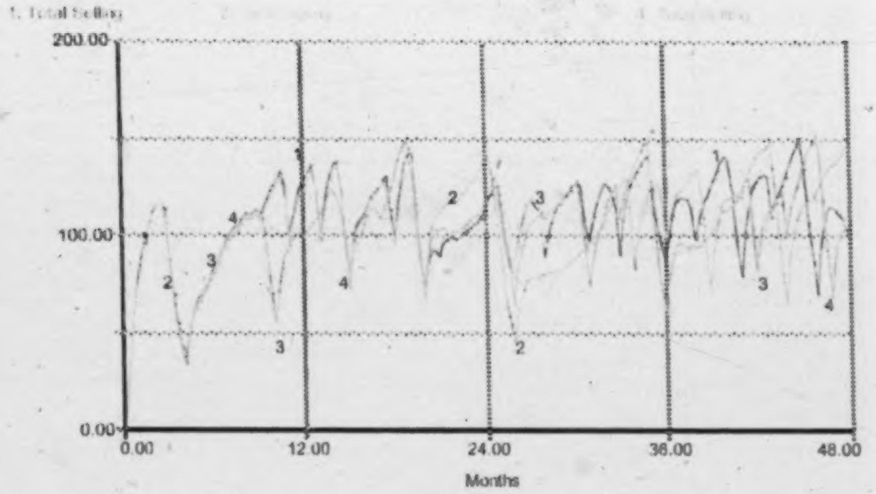

1: Total Revenue
4: Total Revenue
600000.00
300000.00
0.00
1
2
3
4
0.00
12.00
24.00
36.00
48.00
Months

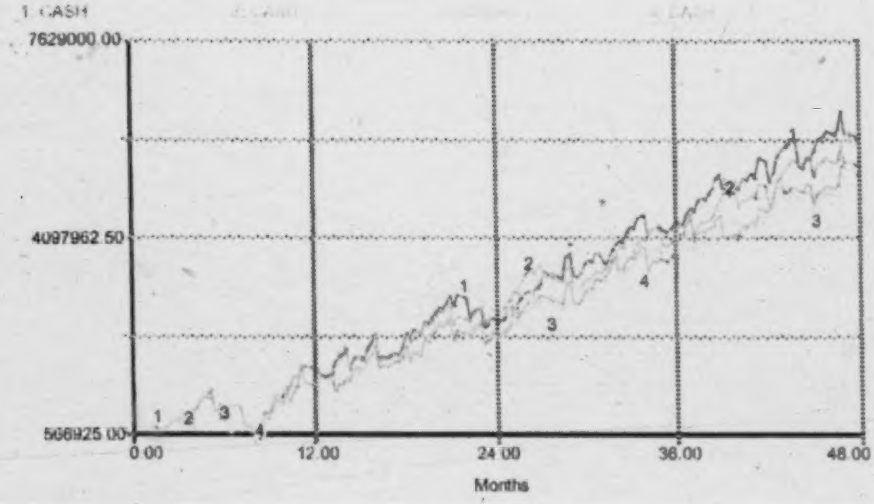


Scrap Rate

Run #	Scrap Rate (Percent)
Run #1	0.5
Run #2	2
Run #3	3.5
Run #4	5

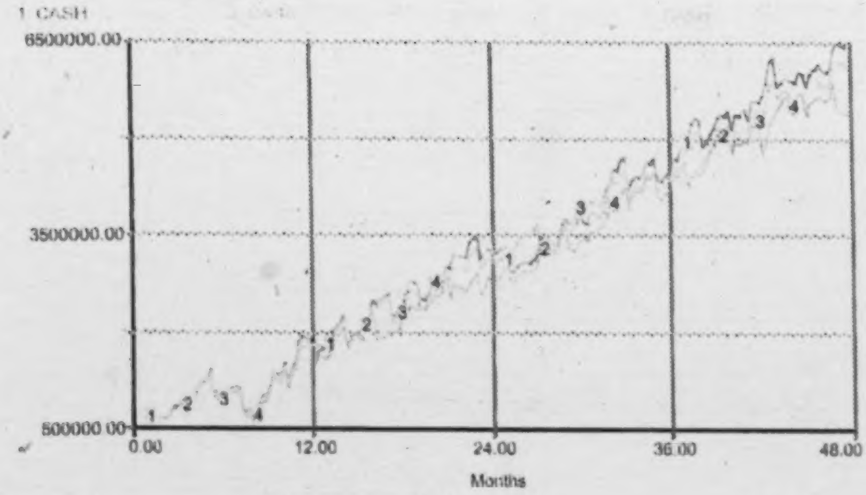






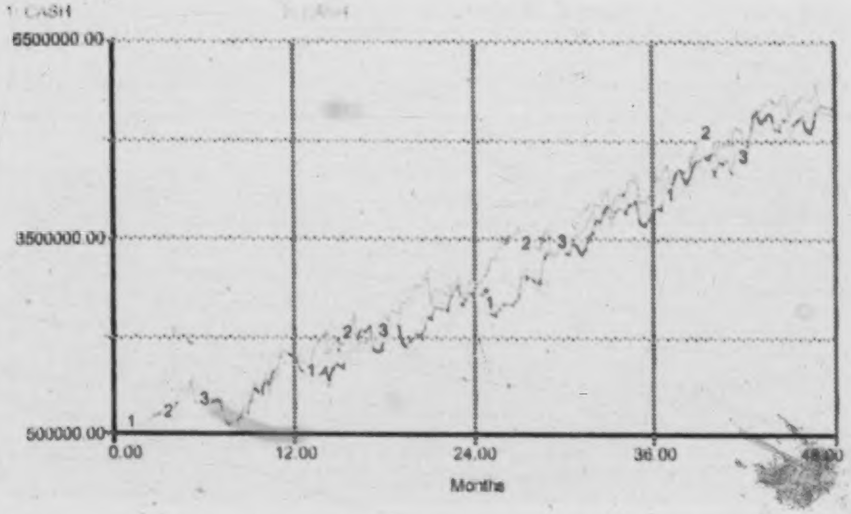
Salary per Employee

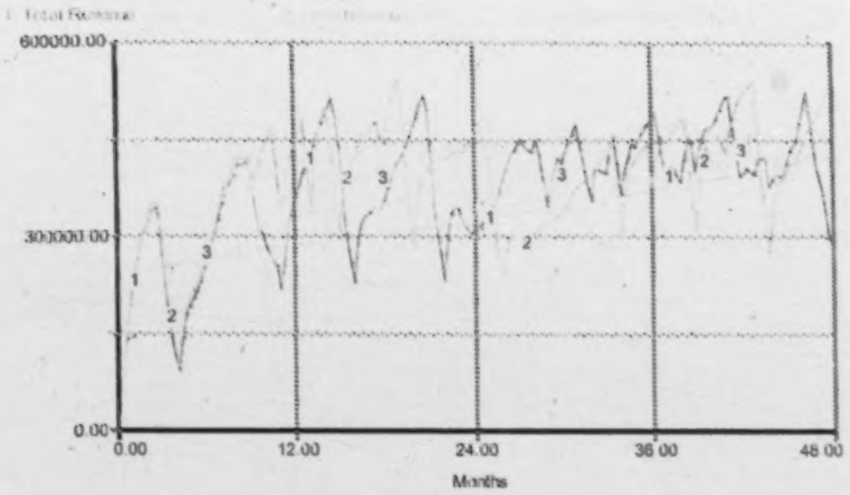
Run #	Salary per Employee ($)
Run #1	2000
Run #2	2333
Run #3	2667
Run #4	3000

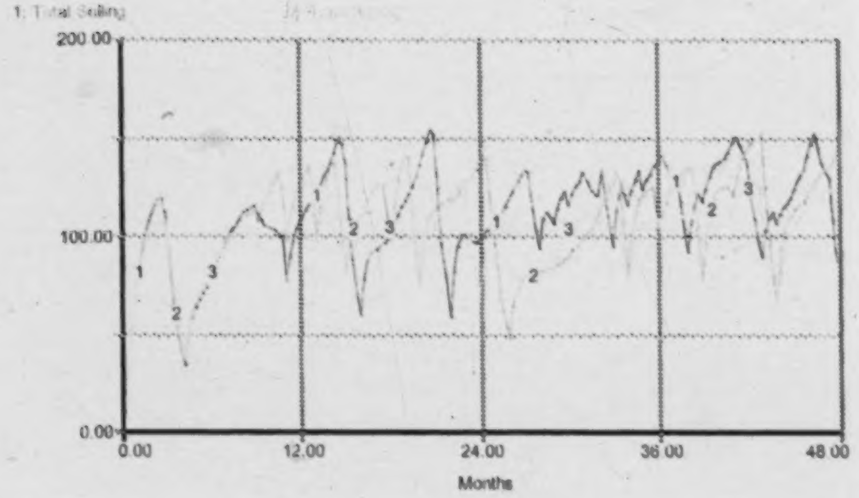


Distributor Price Change ANSI 600

Run #	Distributor ANSI 600 Price ($)
Run #1	5850
Run #2	6500
Run #3	7150

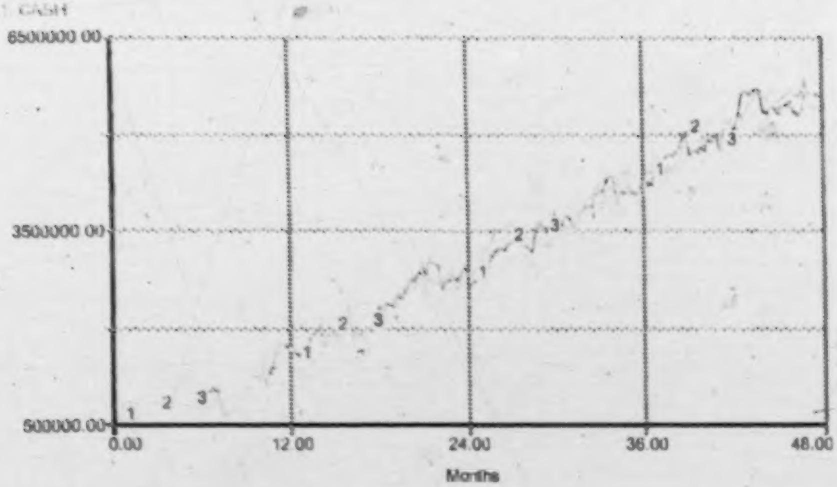






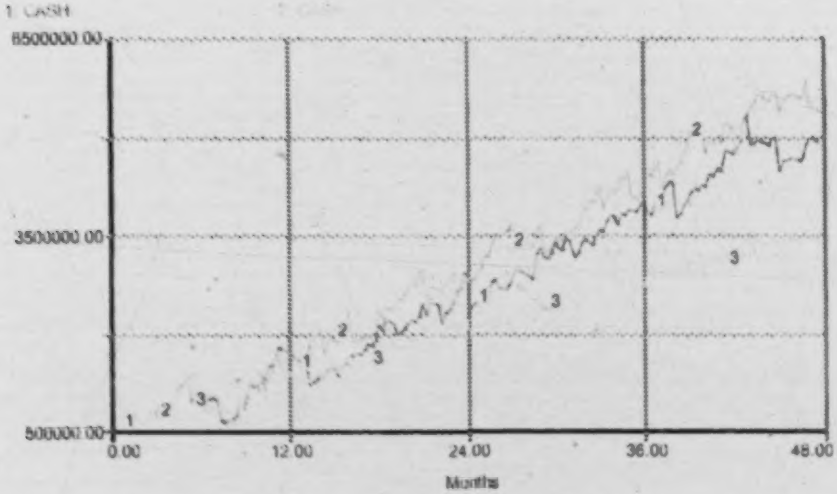
Distributor Price Change ANSI 300

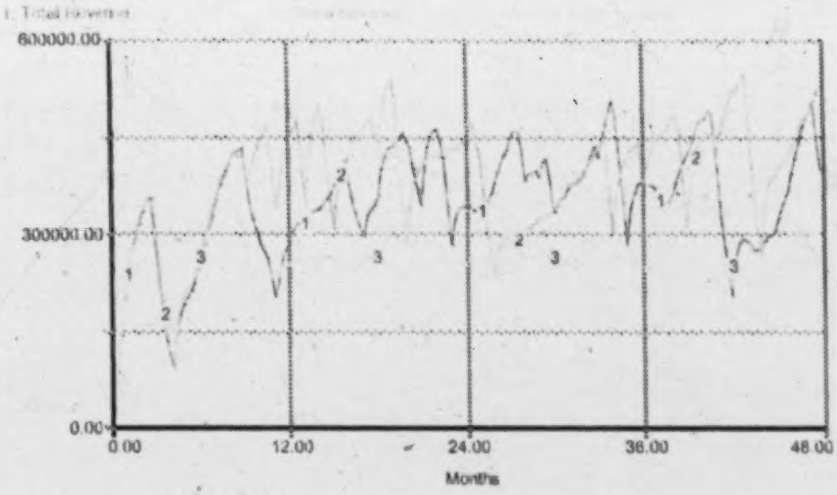
Run #	Distributor ANSI 300 Price ($)
Run #1	2250
Run #2	2500
Run #3	2750

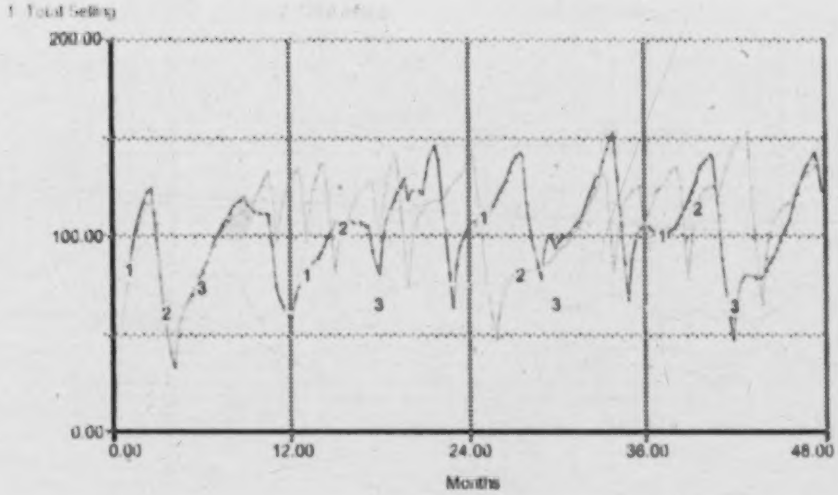


Distributor Price Change ANSI 150

Run #	Distributor ANSI 150 Price ($)
Run #1	1350
Run #2	1500
Run #3	1650

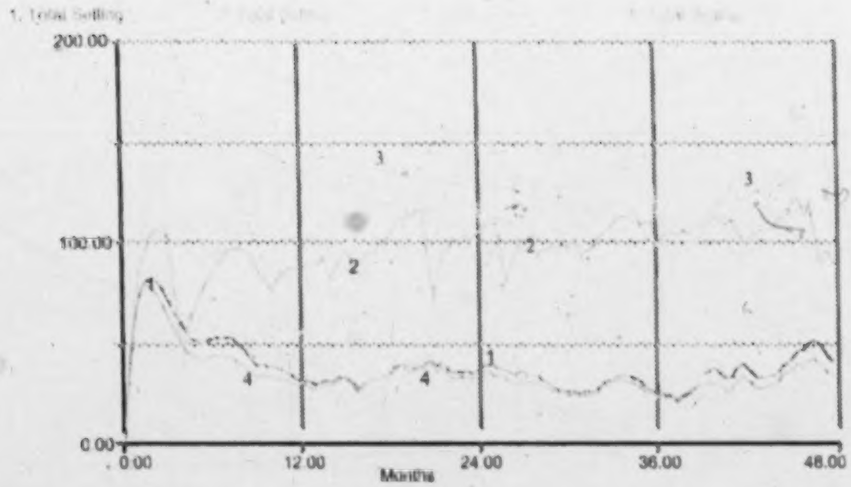


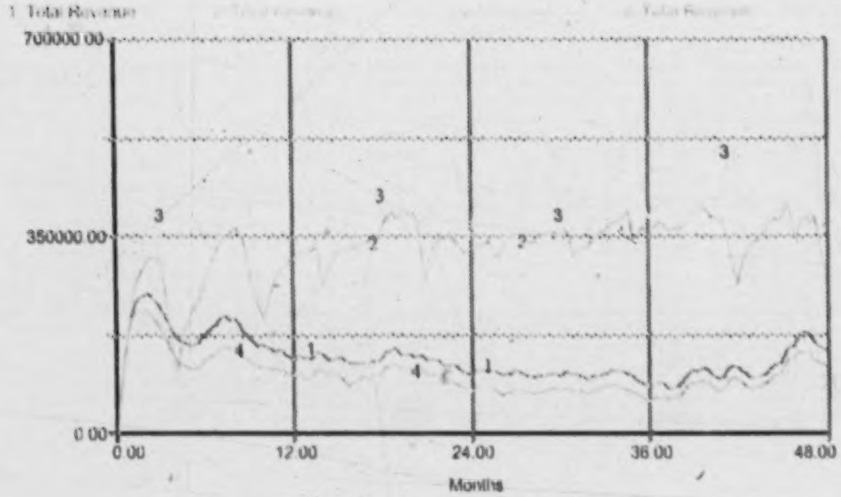


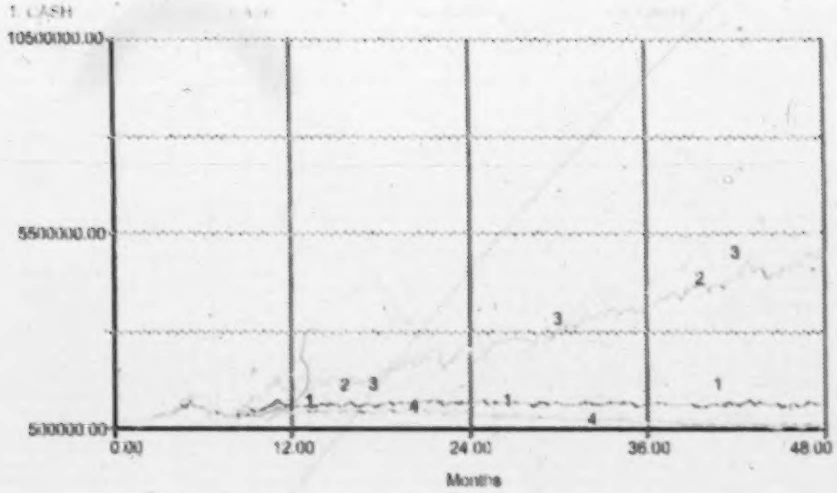


State of Economy

Run #	Price of oil ($/bbl)
Run #1	35
Run #2	28.3
Run #3	21.7
Run #4	15

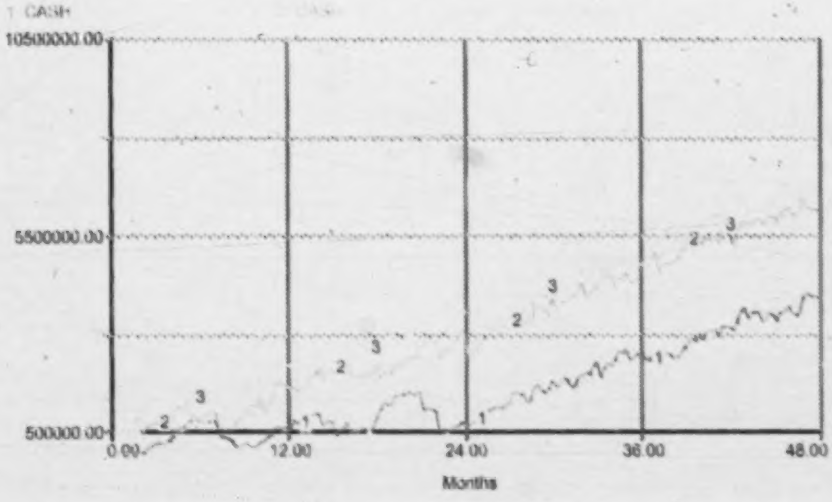

1. Total Selling
2. Total Selling
4. Total Selling
200.00
100.00
0.00
0.00
12.00
24.00
36.00
48.00
Months
1
2
3
4

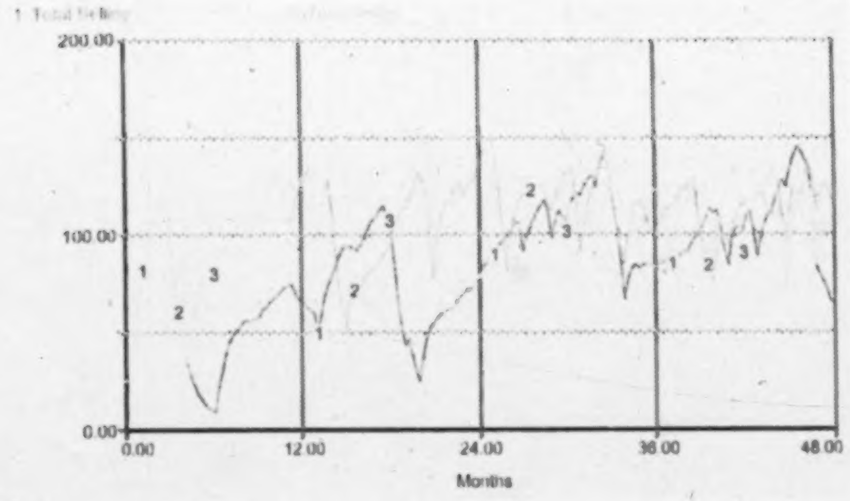

1 Total Revenue
2. Total Revenue
4. Total Revenue
700000.00
350000.00
0.00
0.00
12.00
24.00
36.00
48.00
Months
1
2
3
4



Starting Cash

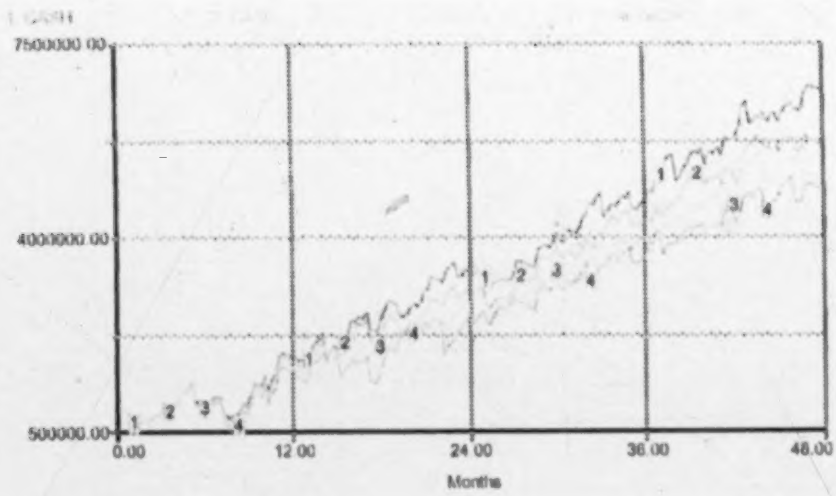
Run #	Starting Cash ($ M)
Run #1	0
Run #2	0.5
Run #3	1.0

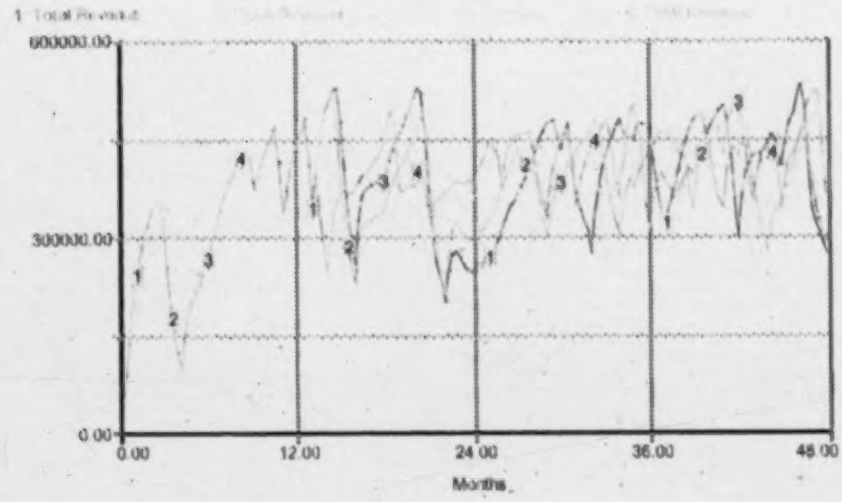


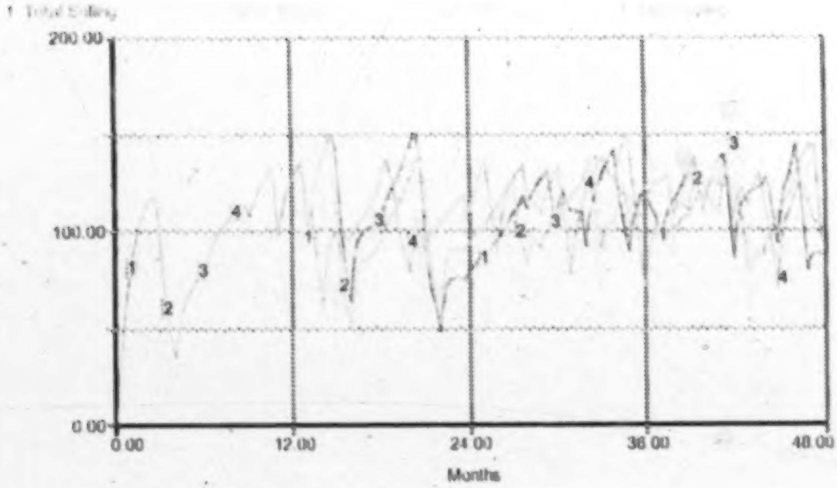


Change in Raw Material Cost

Run #	Raw Material Cost (Percentage of the product price)
Run #1	15
Run #2	18.33
Run #3	21.67
Run #4	25

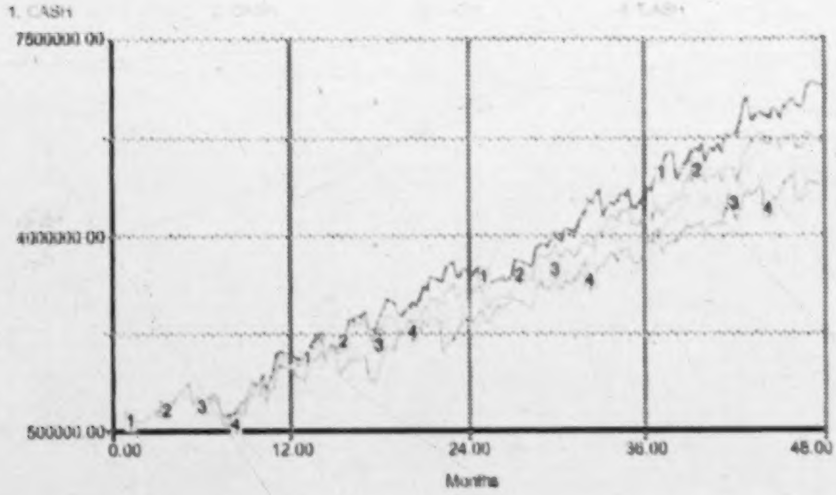

1: CASH
7500000.00
4000000.00
500000.00
1
2
3
4
0.00
12.00
24.00
36.00
48.00
Months

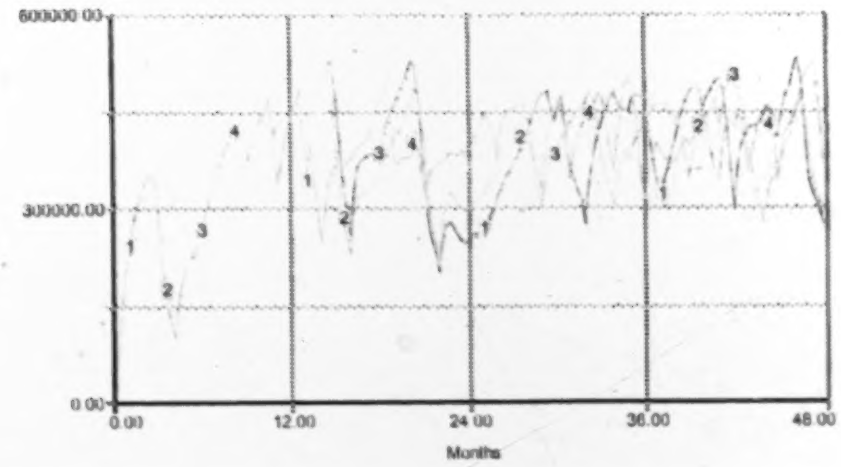

1: Total Revenue
2: Total Revenue
4: Total Revenue
600000.00
300000.00
0.00
1
2
3
4
0.00
12.00
24.00
36.00
48.00
Months

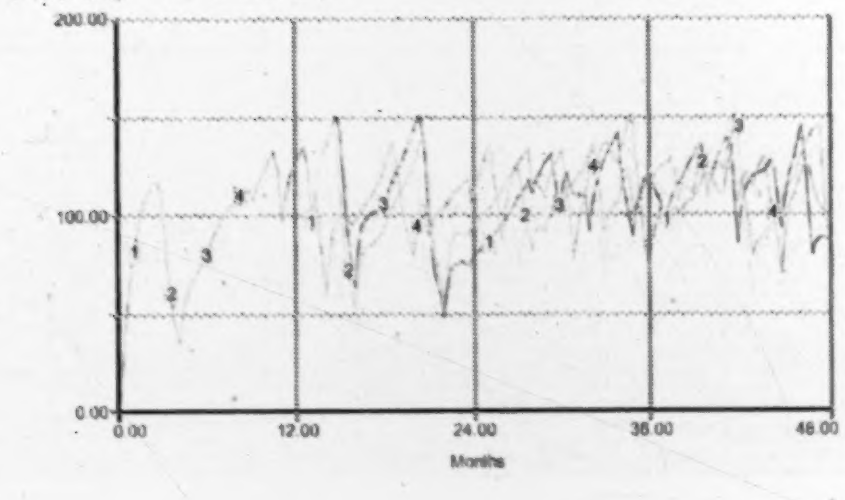


Change in Machining Cost

Run #	Machining Cost (Percentage of the product price)
Run #1	30
Run #2	33.33
Run #3	36.67
Run #4	40




1: Total Revenue
600000.00
300000.00
0.00
0.00
12.00
24.00
36.00
48.00
Months
1
2
3
4


1: Total Selling
2: Total Selling
4: Total Selling
200.00
100.00
0.00
0.00
12.00
24.00
36.00
48.00
Months
1
2
3
4